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VALUE ENGINEERING

CASE STUDIES AND FORMATS FOR PROPOSALS AND REPORTS

A SUPPLEMENT TO THE VALUE ENGINEERING WORKBOOK FOR CONSTRUCTION GRANTS PROJECTS

JUNE 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAM OPERATIONS
MUNICIPAL CONSTRUCTION DIVISION
WASHINGTON, D.C. 20460

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Foreword

In an effort to ensure fiscal and technical integrity in the EPA multi-billion dollar construction grants program, value engineering (VE) applied to project designs has been encouraged since 1974 and was made mandatory for larger projects in 1976. The requirements and detailed guidance for conducting VE studies on EPA funded projects are contained in section 35.926 of the Construction Grants Regulations and the VE Workbook (MCD-29) published in July 1976.

This report supplements the VE Workbook. It contains detailed information on the results of five projects which were voluntarily subjected to VE under actual grant conditions. Also included are (1) formats for VE proposals and reports, and (2) guidance for determining the appropriate level of VE effort.

The report does not present any regulatory requirements. It is primarily a guide to good practice. It will also serve as a reference from which useful information may be extracted. The formats and guidance are included to ensure simplicity in the VE program and thereby the VE process can be effectively and expeditiously executed.

The Environmental Protection Agency intends to revise and update the report as more information is developed through experience. All users are encouraged to submit any pertinent information to the Director, Municipal Construction Division (WH-547), Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, D.C. 20460.

Thomas Jorling

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This report provides guidance on formats for Value Engineering (VE) study proposals and reports; guidance on the appropriate level of VE effort and VE team composition; and case studies on five wastewater projects which were subjected to VE under EPA's voluntary VE program.

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SECTION 1

GUIDANCE ON FORMATS FOR VE STUDY PROPOSALS AND REPORTS

PROPOSALS FOR VE STUDIES

The VE Workbook addresses the considerations to be made in preparing proposals to EPA for VE studies. This report presents more specific outlines of suggested proposal organization. The VE proposal is part of the Step 2 grant application. However, the VE proposal must be a separate section of the application and must contain adequate information so that it can be reviewed independently. The proposal should be complete but concise. It need not explain VE concepts. The following outline is suggested as a guide for submitting VE proposals to EPA.

I. PROJECT INFORMATION

  A. Project name and EPA identification number.

  B. Treatment process and capacity - (Brief description).
    1. Liquid
    2. Solid

  C. Estimated construction (Step 3) costs (grant eligible costs).

  D. Design status.

II. PROPOSED SCOPE OF VE STUDY

  A. Proposed constraints with detailed reasons.

  B. Scope of technical areas to be investigated.

III. PROPOSED ORGANIZATION OF VE STUDY

  A. Timing of the VE study (at what percentage(s) of design completion) and rationale.

  B. Number and length of Workshops (40 hours or less per workshop) and rationale.
    1. Discuss effects on design schedule with overall work plan showing integration of VE effort into design schedule.

2. Number of VE Teams and rationale.

C. Composition of Teams and rationale.
  1. Primary study area for each team.
  2. Specific skills to be included on each team.
  3. Selection criteria for VETC and team members.
  4. List of individual team members and alternates with resumes of each.

D. Plan for Conduct of VE Study.
  1. Pre-Workshop Preparation.
    a. Specific documents to be furnished and distributed and by whom.
    b. Plan for co-ordinating with designer to obtain agreeable basis of costs.
  2. VE Workshop.
    a. Location and day-by-day agenda for workshop.
    b. Plan for availability of design staff to answer questions.
  3. Post Workshop Procedures.
    a. Schedule for oral presentation.
    b. Schedule for preparation and submittal of preliminary VE report.
    c. Schedule for preparation and submittal of final VE report.

IV. VE FEE PROPOSAL (EPA FORM 5700-41, See Page 16 of VE Workbook)

Procurement of VE services and the VE contract must comply with 40 CFR 35.937 of the construction grant regulations. The estimated level of effort for the design firm should be shown separately.

V. PROPOSED VE CONTRACT

VI. APPENDIX - QUALIFICATIONS OF VETC AND TEAM MEMBERS

The following is a sample of Sections I-III of the proposal, illustrating that these sections should be concise.

EXAMPLE VE PROPOSAL, SECTIONS I - III

I. PROJECT INFORMATION

- Project Name - River City, California; Project No. 77D-1014.

- Design Flow = 22 mgd (new plant construction).

- Process - Activated Sludge; Chlorination; Anaerobic Sludge Digestion; Drying Beds.

- Estimated Grant Eligible Construction Costs - $14,200,000.

- Design Status - Step I report approved; No Step 2 work yet done.

II. PROPOSED SCOPE OF VE STUDY

- Constraints - Changes which would necessitate initiation of EIS procedures are not to be made; changes which would result in significantly longer time to implement design and construction are not to be made (i.e., changes which might require extensive new site acquisition or new interceptor routings).

- Technical Areas to be Investigated - Unit process design criteria, structures, electrical, mechanical, plant layout, site.

III. PROPOSED ORGANIZATION OF VE STUDY

- Timing of Study - at 20% of design (insert estimated date); changes easily implemented at this point and most needed data, including costs, will be available.

- Number & Length of Workshops - 1, 1 team workshop.

- Composition of Teams -

  VETC = (Insert Individual & Co. Name)

  List of Team Members and Alternates

  Team Composition
  Mechanical
  Electrical
  Civil/structural
  Sanitary
  Cost Estimator

- Pre-Workshop Activities

  Design Firm: Assemble preliminary plans (which will include I & C drawings) and specifications; project reports, unit quantity takeoffs and unit costs.

  VETC: Co-ordinate with the designer and validate basis of cost estimates; distribute material from designer to team members; arrange facilities for workshop.

- Workshop (Show agenda for each day)

  Day 1
  Day 2

Day 3
Day 4
Day 5

- Post Workshop Schedule

  Oral Presentation - (Insert Date)

  Preliminary VE Report - (Insert Date)

  Review Period for Designer - (Insert Start and Completion date)

  Final VE Report - (Insert Date)

  Implementation Plan - VETC will be retained on a per-diem basis as needed to resolve questions on implementation.

REPORTS ON VE STUDIES

The VE Workbook presents several worksheets and related discussions which will be of use in planning and preparing the VE report. The following outline provides additional guidance on report format and content:

PRELIMINARY VE REPORT(1)

I. INTRODUCTION

   A. Project Name and EPA Identification Number.

   B. Describe timing and scope of VE study.

   C. Describe team responsibilities.

II. COST SUMMARY

   A. Estimate by designer of project costs (capital and operation and maintenance presented separately).

   B. Estimated project costs after VE (capital and operation and maintenance presented separately).

III. SUMMARY OF VE RECOMMENDATIONS

   A. Present Summary Table Shown, Recommended Changes With Following Information.

---

(1) Prepared by VETC so as to be ready for distribution to attendees at oral presentation of VE results.

1. Brief Narrative Description and schematic sketches of before vs. after.
2. Construction, O & M and total savings for each recommendation.
3. Estimated Implementation Costs.

IV. APPENDIX (Separate Volume)

A. Documentation for VE Recommendations.
  1. Validation of Designer's Original Cost Estimates.
  2. Documentation Related to Each Recommended Change.
    a. Description of Recommended Change.
    b. Before and After Design Criteria.
    c. Supporting Calculations on Costs (unit quantities, unit prices, O & M manhours).

B. VE Team Workbooks (For Each Team).
  1. Cost Models
  2. Functional Analysis
  3. Speculative Phase
  4. FAST Diagrams
  5. Idea Evaluation
  6. Cost Analysis
  7. Alternative Evaluation
  8. Team Recommendations

FINAL VE REPORT(1)

I. INTRODUCTION

A. Project Name and EPA Identification Number.

B. Reference Preliminary VE Report for Details on VE Recommendations.

II. SUMMARY OF REDUCTION IN COST FROM ACCEPTED VE RECOMMENDATIONS (including capital, O & M for each item)

III. SUMMARY OF DESIGNER'S EVALUATION OF RECOMMENDATIONS (Each recommendation numbered in accord with number used in Preliminary VE Report).

A. Tabulate Accepted Recommendations.

B. Describe Rejected Recommendations With Reasons For Rejection of Each.

C. Implementation Schedule and Related Costs.

---

(1) Prepared by Designer.

IV. DOCUMENTATION (Data Sources, calculations, etc.) FOR DESIGNER'S REJECTIONS OR MODIFICATIONS OF VE RECOMMENDATIONS.

The following specific recommendations should be carefully reviewed prior to preparation of the VE report:

- Make each VE recommendation brief, clear and complete.
- Don't put unrelated items in the same VE recommendation; make a separate recommendation for each.
- Provide enough information in the VE recommendation (using supplemental pages immediately following it as needed) so that the recommendation is self explanatory and can be understood and evaluated without the need to refer to other documents.
- Each recommendation should be supported by:
  - Before and after design criteria.
  - Before and after sketches.
  - Before and after costs.
  - Information on how costs were developed (i.e.) quantities, unit prices, labor and utility rates, O & M manhours and an explanation of where they came from.
  - A list of other alternatives relating to the recommendations, which were seriously considered, the reasons for their rejection.
- Before and after sketches are very helpful and should be included. These should be clear and should be as detailed as necessary to explain the proposal. They should not however, include unnecessary detail, accuracy or embellishment. Portions or reduced portions of construction drawings are not usually effective.
- A VE recommendation such as "Site team - Relocate chemical building, change site lighting, eliminate unnecessary parking and reduce height of flood control berm - Initial Savings $100,000, LCC Savings $1,200,000", doesn't adequately describe the recommendation to the evaluator or owner. It should be divided into four proposals with each expanded to explain quantitatively what is really being proposed and why.
- Don't waste time and space explaining the history of VE, the reasons for VE, the VE method, the U.S. Government, PL 92-500, how designers design, etc., in the VE report. The report is for the designer and the owner's technical staff along with the funding agencies to review and evaluate.
- Functional analyses, FAST diagrams, cost models, weighting and evaluation sheets, brainstorming lists, etc., should be put in an appendix. Use an adequate table of contents for the detailed

sections of the report and the appendix with a method such as colored pages to set-off the beginning of each recommendation.

Be explicit about the acceptance of rejection of recommendations without saying, for instance: "This recommendation was referred to the electrical engineering department for further analysis". Accept the recommendation or state why it is rejected.

Be consistent in numbering the VE ideas so they can be readily traced from the VE workbooks through the summary portions of the final report. A simple system such as "F-3" to indicate the third idea of the foundation (F) team works well.

SECTION 2

GUIDANCE ON DETERMINING THE APPROPRIATE LEVEL OF VE EFFORT AND VE TEAM COMPOSITION

INTRODUCTION

The appropriate level of VE effort for a given project is a function of several factors, the major ones being: project size, project complexity, constraints upon scope of VE Study, and the degree of completion of the design. This latter point will become less of variable under the mandatory program because projects will plan for VE prior to the initiation of Step 2. As a project progresses through Step 2, the potential for savings through VE decreases because the cost of implementing changes becomes greater. EPA discourages any VE effort after 80% completion of Step 2. The optimum opportunity for return on VE costs appears to be when VE is conducted at 10-30% of completion of the design. The priorities of the design team should recognize the VE effort as a project milestone at the 10-30% point in Step 2 and establish priorities which will insure the availability of material described in the VE workbook. The subsequent discussions of level of effort are based upon conducting the VE study at the 10-30% point in Step 2. The level of VE efforts for studies later than this in Step 2 should be reduced to reflect the reduced potential for return. The major elements to be determined for a given VE study are:

- Total manpower required and number of workshops.
- Number and composition of the VE team(s).

TOTAL MANPOWER REQUIRED AND NUMBER OF WORKSHOPS

Depending on the size and complexity of the project, the VE effort may vary from one team and one study to multiple teams and/or multiple studies in order to adequately review the project. In some larger and/or complex projects, it may be desirable to schedule two VE workshops during the course of the design. The first may occur when 10-30% of the design is complete and would concentrate on basic factors such as project layout; processes used; building systems to be used (steel frame vs. precast walls for example); general approach to electrical, instrumentation, controls, etc. The second workshop would occur when the design is complete enough (approximately 50-60% complete) that a detailed review of the electrical, mechanical, and structural designs could be made.

The determination of how many teams and how many studies must be made on a case-by-case basis. For example, a large advanced waste treatment project may readily justify separate teams, each with a study area such as structures, mechanical, electrical, process, and site. If the system in question is simply an add-on to an existing plant to provide a single process, the level of effort may be relatively small and readily handled in one VE review. On the other hand, a small but highly refined system, to provide the ultimate that today's technology can achieve, would require above average effort.

Typically, one VE team consists of five members. In some cases, larger teams may be justified and have been used on particularly large and complex projects. However, for most projects, the five man team will be an appropriate size. The following components make-up the VE effort:

VE Team Co-ordinator (VETC)

- Pre-Workshop Preparation - Collects project reports, drawings, specifications, quantity takeoffs, and cost data from designer. Also makes arrangements with team members and distributes information to team members.
- Conducts the Project Review Workshop.
- Prepares the Preliminary VE Report.
- Participates in Implementation Phase - as required.

Designer

- Pre-Workshop Preparation - Works with VETC in assembling needed information.
- During Workshop - Provides answers to questions raised by the VE teams (first 2 days of workshop). The designer's participation is passive and any defensive reactions must not be allowed to interfere with the generation of alternative ideas.
- Coordinates Resolution of Questions with VETC and Owner.
- Prepare Final VE Report - In coordination with the Owner, prepares the final VE report.
- Implementation of VE Ideas - This is highly variable and falls outside the scope of the VE Study itself.

Table 1 presents typical levels of effort associated with varying numbers of VE teams for one or two workshops. There may be cases where the first of two workshops utilizes more teams than the second. For example, one five team workshop followed by a later three team workshop would result in an estimated level of effort of 43.5 + 26 = 69.5 man-weeks. Generally the opportunities for changes and ease of implementing changes are

TABLE 1

APPROXIMATE LEVEL OF EFFORT AS A FUNCTION OF THE NUMBER OF VE TEAMS AND WORKSHOPS

LEVEL OF EFFORT-MANWEEKS

	Teams 5 Day Workshop	VETC				DESIGNER(1)				TOTAL, manweeks
		Preworkshop Prep	During Workshop	Report Prep	Followup	Preworkshop Prep	Consult To Teams	Draft Report Response	Co-ord With Owner and Final Report	
1 - 1 team effort	5	1	1	1	-	0.5	0.5	0.5	0.5	10
1 - 2 team effort	10	2	1	2	0.5	1	1	1.5	1	19
1 - 3 team effort	15	2	1	2	1	1	1.5	2	1.5	26
1 - 4 team effort	20	3	1	2	1	1.5	2	2.5	2	35
1 - 5 team effort	25	4	1	3	1	2	2.5	3	2	43.5
2 - 1 team effort	10	2	2	2	1	2	1	1	1	22
2 - 2 team efforts	20	4	2	3	1	2	2	2	2	38
2 - 3 team efforts	30	4	2	3	2	2	2	3	2	49
2 - 4 team efforts	40	6	2	3	2	3	2	5	3	65
2 - 5 team efforts	50	8	2	4	2	4	2	6	4	81

(1) Not including implementation of VE ideas.

significantly greater at the 10-30% design point where the first workshop would be held. Thus, greater VE effort is usually made at this point than at the time of the second workshop. There may be unusual cases where increases over the estimates in Table 1 are clearly justified but drastically greater proposed efforts may indicate that work which should be done as part of the design effort (cost estimation or analysis of alternatives outside of constraints for example) is creeping into the VE effort. As a general guide, the support effort by the designer should not exceed 30% of the VE effort. The designer's estimated supporting level of effort should be considered as a budget guide only with actual payment based on cost-plus-fixed-fee. The effort actually required of the designer will be a function of the number and complexity of VE recommendations. Redesign effort to implement VE recommendations is not part of the VE effort.

The appropriate overall level of effort is chiefly a function of plant size and complexity. Complexity is difficult to quantify. For example, secondary treatment plant complexity itself can vary substantially as a function, for example, of the sludge disposal process (land application of digested sludge is much less mechanically complex than mechanical thickening, dewatering, and incineration). Perhaps the best indicator of potential complexity and the potential for savings from VE is the cost of a given capacity plant. That is, a 20 mgd plant costing $30,000,000 is likely to be more complex and/or offers more potential for savings from VE than a 20 mgd plant costing $14,000,000. Likewise, a 10 mgd plant costing $14,000,000 is more complex than the 20 mgd plant costing $14,000,000 and may justify a larger VE effort.

Based upon a cost analysis of several plants of varying capacity and complexity and an estimation of VE effort for each, a nomograph (Figure 1) has been developed for estimating the appropriate level of VE effort for various size/cost plants. A straight line is drawn from the plant capacity being constructed (the capacity being added in the case of a plant expansion) through the estimated construction cost (excluding engineering, legal, financing, etc. costs). The point at which the extension of this line strikes the right axis of the nomograph provides an estimate of the appropriate level of the VE effort. An example is plotted for a low complexity plant:

20 mgd plant capacity
Estimated Cost = $14,000,000
Estimated level of VE effort = 19 man-weeks
Refer to Table 1 - One, two-team effort appears appropriate

Where only certain components of a plant are being modified or expanded, it may be difficult to develop an applicable "capacity being constructed" value. For example, a plant abandoning land disposal of sludge for a system utilizing mechanical dewatering and incineration might have no associated change in treatment capacity. Such cases will usually involve a limited number of sub-systems and the guidelines in the EPA VE Workbook for projects of limited complexity (page 12) may be used for guidance.

In cases where processes are being added to upgrade plant performance without changing plant capacity, Figure 1 may be used for guidance as illustrated below.

Assume that coagulation, tertiary sedimentation, filtration, and sludge incineration facilities are being added to an existing 50 mgd activated sludge plant with no increase in the existing 50 mgd capacity with the following associated costs:

Rapid Mixing	$130,000
Flocculation	160,000
Clarifier	2,200,000
Filtration	5,600,000
Chemical Feeding:	
Alum	200,000
Polymer, Wastewater	62,000
Polymer, Sludge	580,000
Chemical Sludge Pumping	62,000
Dissolved Air Flotation Thickener	360,000
Vacuum Filter	1,300,000
Multiple Hearth Furnace	7,000,000
Yardwork	2,730,000
TOTAL, CONSTRUCTION COST	$20,384,000

Figure 1 indicates a VE level of effort of about 19 man-weeks for a 50 mgd capacity which has a cost of $20,000,000 (1 - 2 team workshop). With the limited number of sub-systems involved (for example, no extensive site considerations involved because it is an addition to an existing facility), such a level of VE effort appears appropriate. If the same facility were being built as an all new plant, then total construction costs could approach $35,000,000 and the associated level of VE effort would then be about 36 man-weeks (2 - 2 team efforts or 1 - 4 team effort).

VE TEAM COMPOSITION AND QUALIFICATIONS

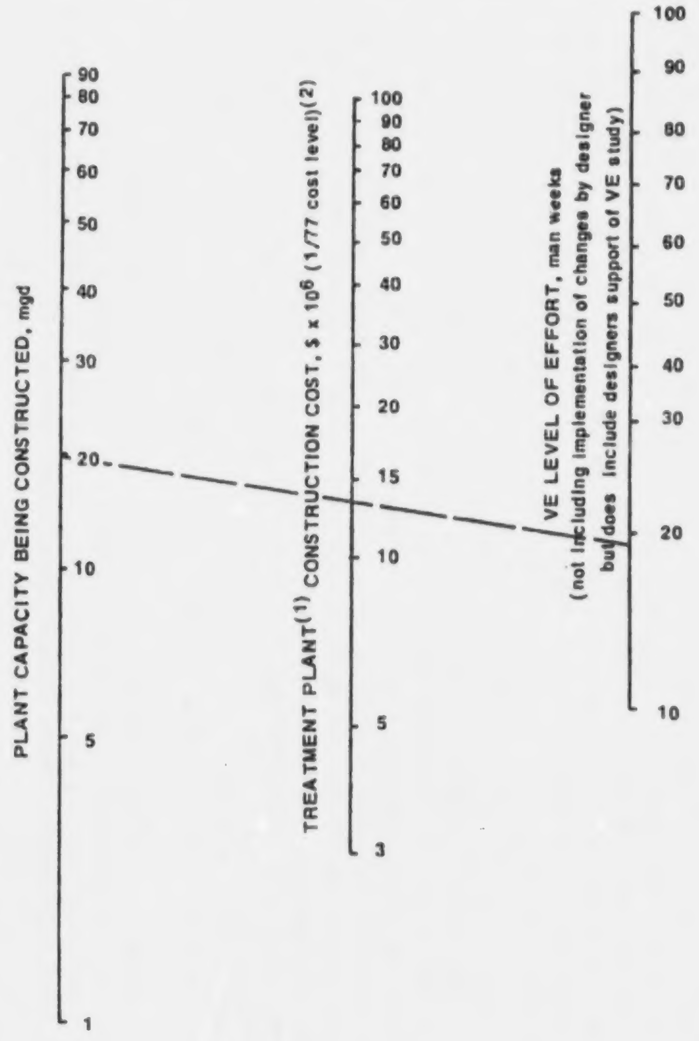
Obviously, the skills and expertise of VE Team Members must be tailored to the nature of the specific project involved. For example, VE of a major land treatment system should involve personnel with agricultural engineering, irrigation system design, and perhaps farm management skills. These skills would be totally inappropriate for a conventional secondary treatment plant project.

Regardless of the specific technical skills required for a project, there are some universally applicable considerations for team members.

Team members should be highly qualified in the disciplines they represent. The competence of the individuals who make up the VE team(s) is probably more important than the precise composition of the teams. The creativity of the teams will be proportional to the competence of their

Figure 1

ESTIMATION OF VE LEVEL OF EFFORT



Note: Any level of VE effort greater than that shown below must be supported by appropriate justification even though the nomograph may indicate a greater value.

Grant Eligible Project Costs	Maximum VE Effort for Avg. Complexity Projects
$ 5,000,000	10 man weeks
50,000,000	50 man weeks
100,000,000	100 man weeks

Any value over 30 man–weeks, consider two separate VE efforts – 1 @ 20% and 1 @ 50–60% of design completion.

(1) Excludes sewer system cost

(2) EPA STP Index = 269.4;
5 mgd Index = 118.88;
50 mgd Index = 130.08.

members, and to judicious selection of the mix of those disciplines. Having too many members from the same discipline on a team may stifle creativity. The participants proposed for the study should have current design, construction, procurement, operation or administrative experience suited to the analysis of the subject design. The importance of the preceding sentences cannot be overemphasized. One team of highly competent, creative individuals may recommend and identify many times the VE savings of several teams of mediocre personnel. Also, the objectivity of the VE Team Coordinator and participants is essential to the success of the VE effort. As noted in the VE Workbook the goals of VE "can only be achieved by all parties working together in a harmonious and constructive atmosphere".

When an outside firm or personnel are used for VE, the VETC and team members should be selected with the advice of the Owner's design firm, but should perform the VE study independently. Seeking the advice of the designer will insure that the designer respects the technical ability and integrity of the VE teams and establishes the basis for the co-operative atmosphere needed for a successful VE study.

As noted earlier, a typical VE team consists of five members. For a conventional secondary treatment plant where a single team is used, useful skills may include an electrical-instrumentation engineer, a mechanical engineer oriented toward pumping-piping systems, a civil/structural engineer, a sanitary engineer, an operator, and a cost estimator available as an advisor. As plant size and/or complexity increases, one may reach the point that five teams, each with emphasis on each of the above technical areas may be needed. Where multiple teams are used, it is desirable that each team has a designated leader who has had VE workshop training and experience as well as the needed technical expertise. It is difficult to generalize on skills needed (i.e., land treatment vs. conventional plants as noted earlier). In all cases, some of the skills may be drawn with beneficial results from the Owner's staff if the needed skills may be found there and are available. Changes in the process selected in Step 1 are normally outside the scope of a Step 2 VE study because of the potential for delays by reopening Environmental Assessment procedures, etc. Thus, team emphasis on sanitary process is usually not provided. Personnel with actual wastewater plant operation and maintenance experience - whether they be electrical, mechanical, civil, in education - should be included when appropriate. Team members with background in construction may also provide a useful perspective. The effort required for coordination of VE teams may be summarized as follows: 1 and 2 team efforts - 1 VETC; 3 teams - 1 VETC plus 1 assistant; 4 and 5 teams - 1 VETC plus 2 assistants.

Some individuals may offer expertise in more than one area (i.e., sanitary-hydraulics). For some processes - particularly AWT processes - chemical engineering skills might well be utilized on some teams. Emphasis in team orientation must reflect local conditions. If, for example, foundation conditions are very straight forward with little potential for savings, this team might be replaced by one solely oriented toward pumping and piping.

It may be practical and beneficial to serve multiple teams with a single cost estimator or a staff of estimators not on the teams.

For projects where two VE efforts are undertaken (10-30% and 50-60% points in Step 2), the second set of VE teams should provide increased emphasis on the construction management and O & M aspects of the project.

An alternative to structuring the teams on a discipline basis (i.e., structural) is to assign teams to process areas such as a team for - sludge processing, one for secondary treatment facilities, etc. Each team would then have a broad range of disciplines (electrical, mechanical, civil, structural, sanitary, etc.).

SECTION 3

VALUE ENGINEERING STUDIES OF FIVE WASTEWATER PROJECTS

INTRODUCTION

This section presents the results of Value Engineering (VE) studies conducted on five wastewater treatment projects under the EPA voluntary VE program. These case studies were made to supplement, with actual field experiences, the VE Workbook (MCD-29) on application of VE techniques to wastewater projects. In order to collect information on the projects, meetings were held with the designer, value engineer, owner, state regulatory agency, and in some cases, Regional EPA personnel on each project. In most cases, each of the parties involved in a given project were interviewed separately in order to obtain their individual views on the VE study. The five VE projects studies were Cleveland, Ohio; Indianapolis, Indiana; Concord, North Carolina; Lebanon, Oregon; and Plainville, Connecticut. The study of each project is presented separately. The goal of each project was to develop the following information:

1. brief description of the project;
2. level of VE effort used and why;
3. designer's role in the project review workshop and the potential impact of that participation on the VE effort;
4. VE recommendations;
5. savings for each change recommended by the VE team;
6. designer's acceptance and rejection of the VE recommendation. Reason and analysis for each rejection;
7. VE fees and implementation costs;
8. net savings in capital and life cycle costs realized as a result of applying VE;
9. general comments (the VE team composition, the implementation process, the role and responsibility of the VE team coordinator from the preworkshop through the implementation processes, etc.).

Based upon the analysis of each of the five projects, some general observations which supplement the guidance provided in the EPA VE Workbook were noted and are presented in the final section of this report. Separate sections present specific guidance on level of VE effort and on recommended formats for VE proposals and reports.

It should be kept in mind that most VE efforts under the EPA voluntary program were made under less-than-optimum conditions. Frequently, the decision to include VE came late in the design effort. Problems experienced with lack of proper preparation for the VE effort and difficulty in implementing changes late in the design effort should be reduced where the VE effort is incorporated in the original design workplan.

LEBANON, OREGON PROJECT

This report is based on interviews held on November 3 and 4, 1976 in Corvallis, Lebanon, and Portland, Oregon with the design firm, VE firm (same as design firm in this case), the municipality, the State Dept. of Environmental Quality, and the EPA Regional office.

Description of the Proposed Project Prior to VE Study

The original Lebanon wastewater treatment plant (trickling filter process) was placed in operation in 1954 with the addition of a secondary clarifier in 1957.

The facility performed satisfactorily. More stringent effluent standards (10 mg/l for BOD and SS during summer months) imposed by the State of Oregon necessitated an upgrading of the plant. A study of the system was completed by the consulting engineering firm in October, 1974. The original plant consisted of the following unit processes:

1. Influent Pumping
2. Headworks (Comminutor and aerated grit chamber)
3. Flow Measurement
4. Primary Clarification
5. Trickling Filter
6. Secondary Clarifier
7. Chlorination
8. Anaerobic Sludge Digestion
9. Sludge Drying Beds

The plant modifications recommended in the October, 1974 study are shown on Figure 2.

The plant expansion was later designed for an average dry weather flow of 3 mgd; average wet weather flow of 7.2 mgd; and a peak hydraulic capacity of 14.5 mgd.

The originally proposed plant expansion included the construction of a new plant pump station with a capacity sufficient to allow all storm flow to receive treatment before it is discharged. This pumping capacity eliminated all bypasses and allowed the abandonment of an existing stormwater pump station. The abandonment of the pump station required the construction of a new 24-inch sewerline parallel to an existing 27-inch sewer to the treatment plant.

The existing plant pump station grit chamber and comminutor basins were abandoned because the location and capacity of these facilities did not lend itself to expansion in a manner which would allow the plant to remain

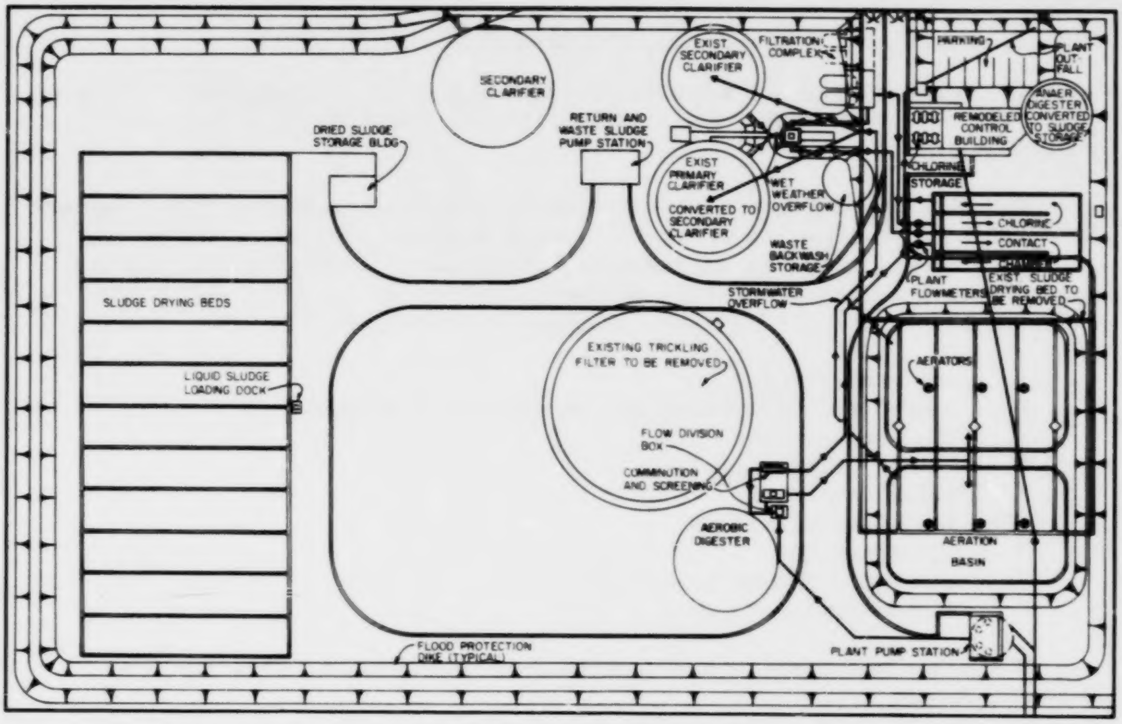

SECONDARY CLARIFIER
EXIST SECONDARY CLARIFIER
FILTRATION COMPLEX
PARKING
PLANT OUT FALL
ANAER DIGESTER CONVERTED TO SLUDGE STORAGE
REMODELED CONTROL BUILDING
DRIED SLUDGE STORAGE BLDG
RETURN AND WASTE SLUDGE PUMP STATION
EXIST PRIMARY CLARIFIER CONVERTED TO SECONDARY CLARIFIER
WET WEATHER OVERFLOW
CHLORINE STORAGE
CHLORINE CONTACT CHAMBER
WASTE BACKWASH STORAGE
PLANT FLOWMETERS
EXIST SLUDGE DRYING BED TO BE REMOVED
SLUDGE DRYING BEDS
STORMWATER OVERFLOW
EXISTING TRICKLING FILTER TO BE REMOVED
AERATORS
LIQUID SLUDGE LOADING DOCK
FLOW DIVISION BOX
COMMINUTION AND SCREENING
AEROBIC DIGESTER
AERATION BASIN
FLOOD PROTECTION DIKE (TYPICAL)
PLANT PUMP STATION

FIGURE 2

PRE-VE PROJECT
LEBANON, OREGON

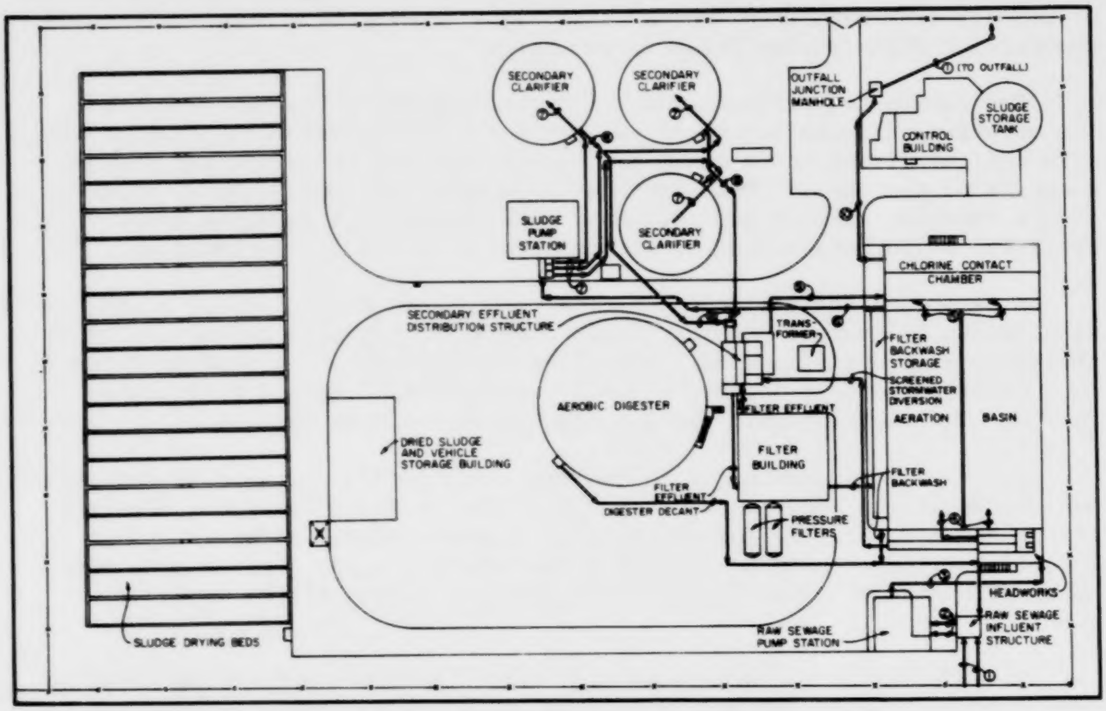

SECONDARY CLARIFIER
SECONDARY CLARIFIER
SECONDARY CLARIFIER
OUTFALL JUNCTION MANHOLE
(TO OUTFALL)
SLUDGE STORAGE TANK
CONTROL BUILDING
SLUDGE PUMP STATION
CHLORINE CONTACT CHAMBER
SECONDARY EFFLUENT DISTRIBUTION STRUCTURE
TRANS-FORMER
FILTER BACKWASH STORAGE
SCREENED STORMWATER DIVERSION
AEROBIC DIGESTER
FILTER EFFLUENT
AERATION
BASIN
DRIED SLUDGE AND VEHICLE STORAGE BUILDING
FILTER BUILDING
FILTER BACKWASH
FILTER EFFLUENT
DIGESTER DECANT
PRESSURE FILTERS
HEADWORKS
RAW SEWAGE INFLUENT STRUCTURE
RAW SEWAGE PUMP STATION
SLUDGE DRYING BEDS

FIGURE 3

POST VE PROJECT
LEBANON, OREGON

in operation during construction. The space occupied by these facilities was used to provide storage for chlorine and miscellaneous plant equipment and supplies.

The new plant pump station would pump the raw sewage to a new headworks consisting of a flow division box,comminutor, and hydrasieve screen. The flow division box allowed a flow of up to 8 mgd to pass through the comminutor and on through the rest of the plant. Storm flows in excess of 8 mgd were split to a hydrasieve screen where the sewage receives the equivalent of primary treatment after which it flows by gravity to a chlorine contact chamber for disinfection prior to discharge.

The comminuted effluent would flow by gravity to the aeration basin. The aeration basin consisted of two cells for flexibility of operation with each cell utilizing three 20-hp mechanical aerators to aerate and mix the contents of the basin. The aeration basin effluent would flow by gravity to the existing primary and secondary clarifiers. The existing primary clarifier would be modified so it can serve as a secondary clarifier.

A secondary effluent pump station pumped secondary effluent to the mixed media filtration complex. The filters are required to meet the more stringent effluent standards. The filtered effluent would flow by gravity to a chlorine contact chamber where it would be disinfected before discharge. The existing chlorination facilities would be expanded.

Other proposed additions to the plant included a new aerobic digester, new sludge drying beds, and conversion of the existing anaerobic digester into a storage facility for aerobically digested sludge. The existing trickling filter was to be removed. The existing sludge drying beds were to be relocated to allow for a more economical layout of the expanded plant.

In addition to the drying beds, a liquid sludge loading dock would be provided near the sludge drying beds to enable flexibility for truck haul of liquid digested sludge to farmlands as a fertilizer. A dried sludge storage building would be provided to allow stockpiling of dried sludge. It was assumed that the ultimate disposal of the digested waste solids would be on local farmland as a fertilizer - a successful, established practice at Lebanon.

The cost of the originally proposed design was estimated at $3,565,000 (March, 1977 basis including engineering, legal, administrative costs). Costs are discussed in more detail later in this report.

The VE Study

Organization--

The VE study was conducted in 1976 by the same firm that was performing the design. One VE team included an engineer from outside the design firm. The Lebanon City Engineer also served on two of the VE teams.

Three VE teams were used for this project. Team #1, called the "overview team," began its study at 15 percent of design completion. Team #1's main area of concentration was major design concepts, facilities plans, and processes. Some ideas were remanded from Team #1 to two succeeding VE teams. Team #2 called the "architectural - structural team" and Team #3 called the "mechanical, electrical, instrumentation and control team", made subsequent studies at the 25 percent design stage.

The composition of the teams was as follows:

VE Team 1 - Overview Team
Electrical Engr. - Team Leader (also VE director for firm and VETC for study)
Sanitary Engr.
Mechanical Engr.-(from outside consulting firm)
Architectural Consultant
Civil Engr. - (City Engineer for City of Lebanon).

VE Team 2 - Architectural - Structural Team
Electrical Engr. - Team Leader (also VE director for firm)
Structural Engr.
Civil Engr.
Sanitary Engr.

VE Team 3 - Mechanical, Electrical, I & C Team
Mechanical Engr. - Team Leader
Sanitary Engr.
Instrumentation & Control
Electrical Engr.
Civil Engr. - (City Engineer for Lebanon)

In addition to the value engineering and design teams, a review team was formed. Senior engineers from the design firm comprised this review team. The function of the review team was to compare the original design as conceived by the design team, with the alternative design as conceived by the value engineering teams. If a VE team proposal was accepted by the review team, the design team was instructed to incorporate the modification into the design. If a VE team proposal was rejected by the review team, a full explanation was given for the rejection.

The composition of the review team was:

4 Sanitary Engrs. (1 was Team Captain)
Structural Engr.
2 Mechanical Engrs.
Architect

One of the four sanitary engineers on the review team was also the project design engineer. No members of the design team served on the VE teams.

Team 1, the overview team, gave more emphasis to general brainstorming than did the subsequent VE teams 2 and 3. Team 1 met for 3 days at 15% of design completion. Teams 2 and 3 each met for 40-hour sessions and generated some new ideas as well as evaluating in detail several ideas proposed by Team 1.

Level of VE Effort

The above paragraphs summarize the manpower devoted to the VE teams. The total fee for the VE study was $29,500, including the supporting efforts by the design personnel. The VE study was conducted as a lump sum amendment to an existing contract between the City and the design firm for the design of the Lebanon plant. The initiative for the VE study came from the designer who made a presentation to the City Council on the merits of VE. The following advantages of an in-house VE team as compared to an outside VE team were presented. With an in-house VE team, the designers know the qualifications and motives of the VE team members whereas with an outside firm doing the study, qualifications, motives, and attitudes of the participants are unknown.

Following approval of the VE study by the City, the design firm gained the approval by the State of Oregon Department of Environmental Quality (DEQ) for grant funding. The VETC felt that the level of VE effort for the Lebanon project will serve projects of comparable complexity in the $3,000,000 - $20,000,000 range. He feels that the one preliminary VE team early in the design followed by two VE teams represents a minimum level of effort in this cost and complexity range. The VETC has experimented with team workshop periods greater than 40 hours and has concluded that the benefits gained are not proportional to the added cost. The review team and cost estimator used in the Lebanon study performed outside the 40 hour limitation but the 3 VE teams accomplished their work within 40 hour periods (24 hours for VE Team 1). A key element in the VE work was having design team cost estimates available for VE teams 2 and 3 so that VE teams did not have to develop cost estimates for the proposed design. The 25-30% design completion used for detailed VE at Lebanon is viewed by the design firm as the optimum point for VE because they believe that the inflationary cost increases from delays encountered in acceptance and implementation of VE recommendations at later stages of the project (i.e., 60-70% design completion) will offset an undesirable proportion of any savings that might be realized. One of the major changes resulting from the VE study at Lebanon (related to a change in the chlorine contact basin as described later) was easily implemented without causing delays or incurring redesign costs because the chlorine contact basin design had not yet been detailed at 25% design completion.

VE Study Summary

At the beginning of the information phase, the Overview VE team gathered all of the available design documents, including a conceptual cost estimate shown in Table 2.

TABLE 2. CONCEPTUAL COST ESTIMATE - LEBANON, OREGON PROJECT (Input Data to VE Teams)

		Estimated Cost
West Side Pump Station		$110,000
Primary System		
Plant Pump Station	$70,000 bldg.	300,000
Influent Sewer		50,000
Comminutor/Hydrasieve		73,000
Splitter Box		4,200
	Subtotal	$427,200
	Say	$430,000
Secondary System		
Aeration Basins		120,000
Aeration Equipment		132,000
RAS Pump Station	$27,000 bldg.	48,000
Secondary Clarifier		100,000
Splitter Box		4,200
Secondary Effluent Pump Station		48,000
Cl_2 Contact		120,000
Flow Meas.		15,000
Final Effluent Pump Station		50,000
	Subtotal	$637,200
	Say	$640,000
Tertiary System		
Mixed Media Filter	$22,500 bldg.	$198,000
Solids Handling		
Digester Repairs		6,000
Drying Beds		192,000
Aerobic Digester		71,500
Storage		5,000
	Subtotal	$274,500
	Say	$275,000

TABLE 2 (Continued)

		Estimated Cost
Support Facilities		
Control Building		$ 7,500
Landscaping		25,000
Painting		20,000
Plant Piping		126,000
I&C		18,000
Electrical		162,000
	Subtotal	$358,500
	Say	$360,000
Summary Table		
West Side Pump Station		$110,000
Primary System		430,000
Secondary System		640,000
Tertiary System		198,000
Solids Handling		275,000
Support Facilities		360,000
	Subtotal	$2,013,000
Contingencies, 15%		302,000
	Subtotal	$2,315,000
*Construction Cost Adjustment (40%)		926,000
	Subtotal	$3,241,000
Estimated Eng., Legal & Admin (10%)		324,000
	Total Project Cost	$3,565,000
	Less Federal Grant	$2,673,750
	Net Cost to City	$891,250

*July 1974 to Mar 1977 = 32 mos. @ 1.25%/mo.

After examining information supplied to them, the Overview team formulated a Functional Analysis System Technique (F.A.S.T.) diagram for this wastewater plant (Figure 4). A cost model (Figure 5) was then developed to identify those functions that have a poor cost-to-worth ratio. The worth concept used in developing such cost models is no longer being used by the designer because of the difficulty in establishing reasonable worth values for wastewater project components and because they feel that the F.A.S.T. diagram is much more useful in determining areas subject to improvement through brainstorming. The worth values shown in Figure 5 were based on "gut" feels on lowest-cost approaches or where they "could cut 10%," etc. The cost-to-worth ratios determined are quite low.

The first four hours of each of the three VE sessions was devoted to the designer briefing the VE team on the project. Each of the three VE teams then entered the speculative phase. There were no constraints placed on the scope of ideas. The ideas generated were then ranked during the analytical phase on a scale from 1 to 10 (10 being the top of the scale for the ideas judged to be of most potential). In practice, the ranking system amounted to a "fail-or-pass" system. If any member of the VE team felt an idea was worth pursuing, it was given a ranking of 5 or more. The design firm now uses a "fail-or-pass" system rather than attempting any numerical rankings at this stage. The balance of disciplines on the VE team enabled, for example, ideas proposed by a sanitary engineer which might be clearly unworkable from an electrical standpoint to be eliminated. Those ideas which passed this initial screening were then subjected to a detailed preliminary engineering evaluation to minimize the time that the design team might spend on ideas which would be found to be worthless if they were only pursued far enough. Documentation of these evaluations of even clearly unworkable ideas is included to ease future VE efforts which may generate the same ideas. In areas where the design hadn't progressed far enough for detailed calculations, the idea was noted and passed on to the design team. In some cases, major assumptions had to be made to perform the economic analyses. These assumptions were noted in the VE report.

Ideas which passed these first two analyses, were presented to the review team. The review team then compared this new alternative to the original design and decided which of the two designs was to be used. Table 3 summarizes the VE ideas which were recommended to the review team by the VE teams but which were rejected.

Table 4 presents the VE ideas which were accepted by the design team. Costs to implement the VE changes were not defined but were considered "minimal" because there was little impact on already completed design work. No delays resulted. The DEQ accepted the proposed changes although they did request automated freeze protection for any outdoor pumps. Figure 3 presents the post VE layout of the plant.

About 50% of the projected savings from the VE study were related to the repositioning of the chlorine contact chamber. The raising of the contact chamber requires pumping of secondary effluent to the chamber at all times. The DEQ remains uncertain as to whether or not the added power and

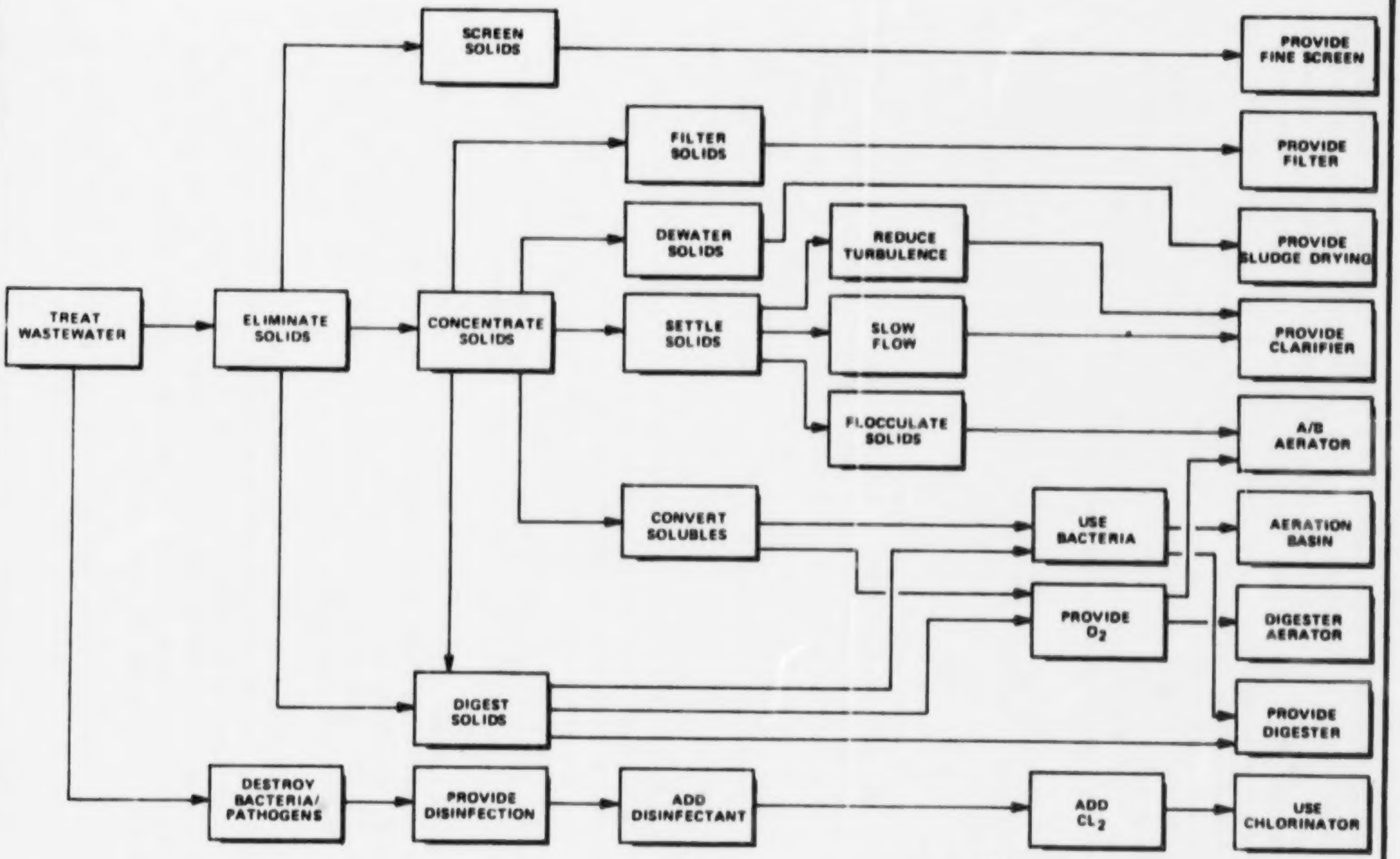

TREAT WASTEWATER
ELIMINATE SOLIDS
SCREEN SOLIDS
CONCENTRATE SOLIDS
DIGEST SOLIDS
DESTROY BACTERIA/ PATHOGENS
FILTER SOLIDS
DEWATER SOLIDS
SETTLE SOLIDS
CONVERT SOLUBLES
PROVIDE DISINFECTION
ADD DISINFECTANT
REDUCE TURBULENCE
SLOW FLOW
FLOCCULATE SOLIDS
USE BACTERIA
PROVIDE O_2
ADD CL_2
PROVIDE FINE SCREEN
PROVIDE FILTER
PROVIDE SLUDGE DRYING
PROVIDE CLARIFIER
A/B AERATOR
AERATION BASIN
DIGESTER AERATOR
PROVIDE DIGESTER
USE CHLORINATOR

FIGURE 4

LEBANON WASTEWATER TREATMENT FACILITY
F.A.S.T. DIAGRAM

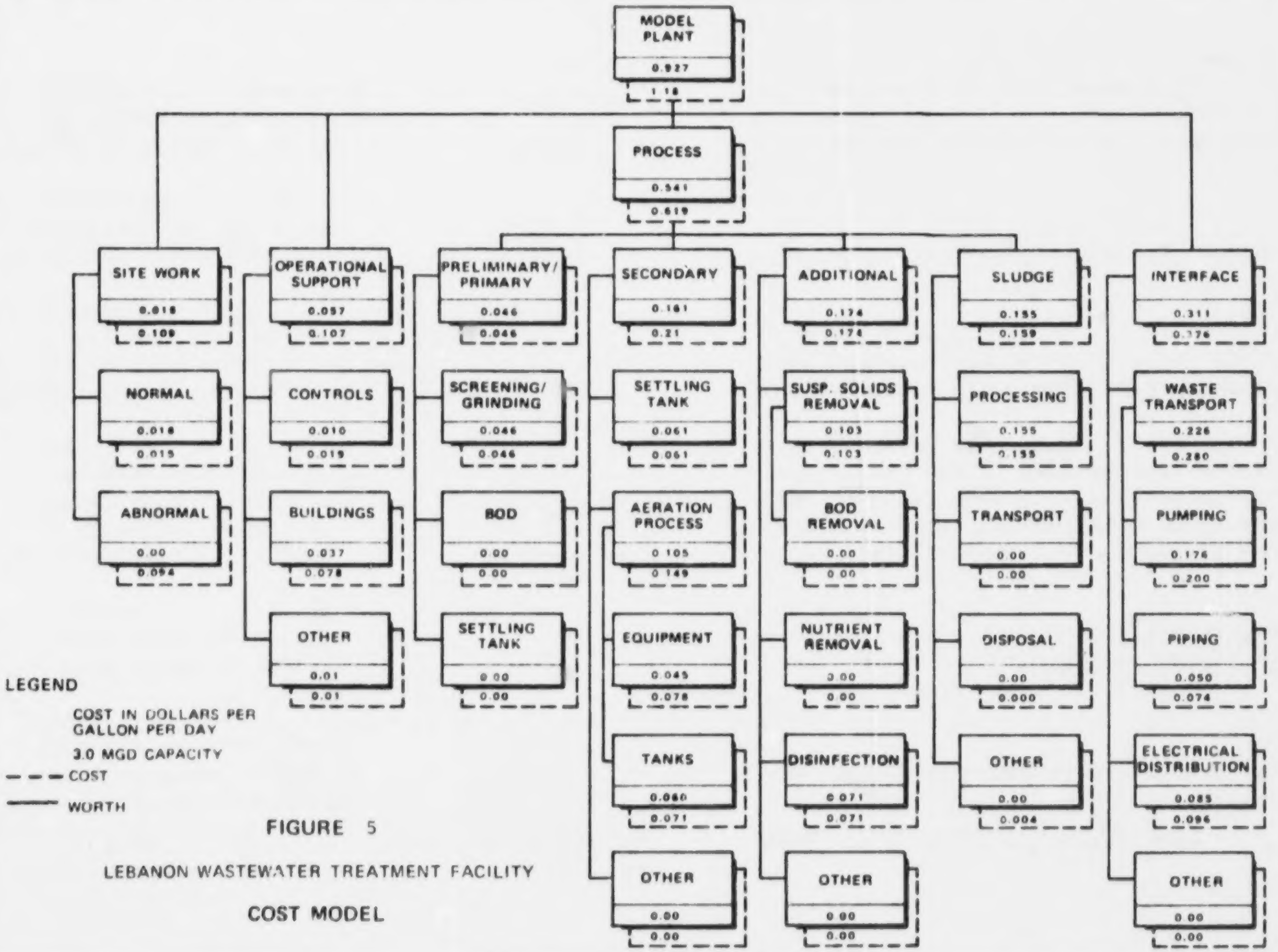

MODEL PLANT
0.927
1.18
PROCESS
0.541
0.619
SITE WORK
0.018
0.109
NORMAL
0.018
0.015
ABNORMAL
0.00
0.094
OPERATIONAL SUPPORT
0.057
0.107
CONTROLS
0.010
0.019
BUILDINGS
0.037
0.078
OTHER
0.01
0.01
PRELIMINARY/ PRIMARY
0.046
0.046
SCREENING/ GRINDING
0.046
0.046
BOD
0.00
0.00
SETTLING TANK
0.00
0.00
SECONDARY
0.161
0.21
SETTLING TANK
0.061
0.061
AERATION PROCESS
0.105
0.149
EQUIPMENT
0.045
0.078
TANKS
0.060
0.071
OTHER
0.00
0.00
ADDITIONAL
0.174
0.174
SUSP. SOLIDS REMOVAL
0.103
0.103
BOD REMOVAL
0.00
0.00
NUTRIENT REMOVAL
0.00
0.00
DISINFECTION
0.071
0.071
OTHER
0.00
0.00
SLUDGE
0.155
0.159
PROCESSING
0.155
0.155
TRANSPORT
0.00
0.00
DISPOSAL
0.00
0.000
OTHER
0.00
0.004
INTERFACE
0.311
0.376
WASTE TRANSPORT
0.226
0.280
PUMPING
0.176
0.200
PIPING
0.050
0.074
ELECTRICAL DISTRIBUTION
0.085
0.096
OTHER
0.00
0.00
LEGEND
COST IN DOLLARS PER GALLON PER DAY
3.0 MGD CAPACITY
– – – COST
—— WORTH

FIGURE 5

LEBANON WASTEWATER TREATMENT FACILITY

COST MODEL

TABLE 3. IDEAS RECOMMENDED BY VE TEAMS REJECTED BY REVIEW TEAM

Idea recommended by VE Team	Potential Life Cycle Savings	Basis of Decision of Review Team
Remove line which permits waste of mixed liquor directly from aeration basin.	$52,700	Cost is justified in light of increased flexibility and operational simplicity.
Use High Speed Aerators rather than Low Speed Aerators.	$38,500	Plant has no primary sedimentation. Impellers of high speed aerators may plug with rags.
Use outdoor rated eqpt. to eliminate need for filter bldg., influent pump sta. and RAS pump sta.	$63,600	Retain filter bldg. to ease operation and maintenance of chemical feed eqpt; retain RAS pump sta. for operator convenience and aesthetics; design team should re-evaluate influent pump sta.
Modify aerator supports so that aeration basin outside wall and center walkway is removed.	$18,397	Inconvenience of access would discourage adequate maintenance which might increase cost in the long run.
Eliminate brick facade on buildings by use of pre-engineered buildings.	$17,000	Use brick for aesthetics and sound isolation.
Use earthen lagoon with lining for filter backwash storage instead of concrete tank.	$15,100	Firm has had poor experience with pond liners in wastewater service, solids get under liners through tears and generates methane gas which floats liner. When pond is drained, high ground water could float liner.

TABLE 3. (CONTINUED)

Idea recommended by VE Team	Potential Life Cycle Savings	Basis of Decision of Review Team
Use wood tank for filter backwash storage instead of concrete tank.	$ 9,300	Tank will be partially below grade. Not general practice to bury structures of this type. May not achieve 20 year life. If tank dries out, may be difficult to make water tight.
Use steel tank for filter backwash storage instead of concrete tank.	$ 5,700	Hydraulic pressure from high ground water on empty tank generates special problems.
Use fixed filter influent rate with recycle to simplify control system.	$15,500	Savings overstated, would be pumping 6 mgd even when average flow initially is less than 1.7 mgd causing unnecessary power consumption. If chemicals added, would increase chemical cost. More frequent backwashes.
Eliminate backwash waste storage tank and discharge backwash water directly into raw sewage wet well.	$36,900	Attempt to utilize interceptors for storage limits flexibility of when filters can be used. Control system required more costly than VE estimated.
Manually control RAS flow by use of pressure gauges as indication of flow with operator adjustment of valve.	$26,850 - $38,190	Primary concern with manual setting of valves is likelihood of plugging with rags. Flow determination from discharge pressure may not be practicable.
Provide motor control panel with only annunciator and flow recorders. Eliminate motor status lights.	$ 4,800	Motor status lights felt to be necessary for efficient operation.

TABLE 4. VE IDEAS ACCEPTED BY DESIGN TEAM

	Est. Potential Saving		
	Net	Initial	Life Cycle
Use of dual-medial filters instead of mixed-media filters.	$20,000	$20,000	-
Use the existing trickling filter for an aerobic digester instead of building a new digester.	$52,900	$44,000	$ 8,900
Use common wall construction between the chlorine contact chamber and aeration basin.	$27,058	$27,058	-
Reposition the effluent pump station ahead of the chlorine contact chamber thus allowing the entire chamber to be raised out of difficult excavation area.	$108,600	$108,600	-
Use the basement area of the existing control building for storage of selected items instead of enlarging the influent pump station.	$12,212	$12,212	-
Use outdoor pumps and drives as much as possible at all pump stations.	$15,000	$15,000	-
Build the third stage of the filter building now but use it to store the hydraulic flusher truck, eliminating future construction.	N/A	N/A	N/A
Relocate the power control center from the influent pump station to the filter building.	$18,000	$18,000	-
Install an automatic restart unit for plant process drives to counteract manual restart following a power bump. Eliminates need for off-hour calls for operators to restart power.	$10,000	$-4,000	$14,000

TABLE 4. (CONTINUED)

	Est. Potential Saving		
	Net	Initial	Life Cycle
Relocate the plant control panel from an interior building wall to an exterior building wall.	$ 5,000	$ 5,000	-
Use telephone dialing system for alarm rather than using leased telephone lines.	$ 3,000	$ 800	$ 2,200
Eliminate filter surface wash pumps and use plant water.	$ 3,000	-	-
TOTAL	$274,770	$249,670	$25,100

capital costs for continuous pumping were adequately considered. The VE report does not quantify these added costs. The DEQ was also concerned that all the costs associated with relocation of piping and the distribution box to permit relocation of the chlorine contact chamber may not have been fully recognized.

The DEQ also raised some questions at the time of the VE report about the justification for the added capital costs for the restart unit for automatic restart of motors following a power bump. An analysis of the O & M savings led to the conclusion that it was a cost/effective item.

As can be seen from Table 4, about 90% of the VE savings were related to initial, capital costs with about 10% related to O & M savings. O & M savings were estimated over a 20 year period.

A review of the project final plans and specifications was made to determine how the items in Table 4 were incorporated. The specifications still provided for the original mixed media filters with the dual-media option being noted in the specifications as an acceptable alternate if the supplier provides satisfactory performance data to the engineer. Any redesign required for the alternative filter systems was specified to be the responsibility of the supplier. The other major VE items were incorporated essentially as suggested by the VE teams.

The DEQ reported that the Step 3 grant application for the Lebanon project showed a slightly higher project cost than the pre-VE estimates which had been made on a March, 1977 basis. The DEQ recognized that the final estimate was a more detailed estimate and that inflationary influences were now real rather than projected. However, they were concerned about how one can effectively evaluate the savings actually resulting from VE under these conditions. The project construction bid on December 8, 1976 with a low bid of $3,795,000 - some $500,000 over the initial post VE estimate and nearly $300,000 over the Step 3 grant application value.

The final VE report was summarized to the City Council by the design/ VE firm with a verbal presentation.

General Observations

The design team personnel felt the VE process offered a welcome review and that the VE review will make for a better effort on the next design. The design personnel appear to have an increased awareness of costs in the early design phases knowing that a VE effort will be made. The design firm now incorporates the VE efforts as project milestones in the basic project workplans to insure that all needed data are available to the VE teams. Process and instrumentation drawings have been found to be an especially important item for the VE study.

The designer feels that in-house VE studies have merits which should be carefully considered. In-house studies offer more rapid and more complete communication, an essential element if the VE study is to be successful. Inclusion of some VE team members from outside the design firm helps to insure the client that objectivity is maintained.

The basic client reaction (expressed by the City Engineer) was favorable to the VE study. He felt that the fact that it was an essentially in-house VE study did not inhibit the objectivity and thoroughness of the VE study. He felt the timing of the VE study was excellent and that there were no implementation problems associated with the VE suggestions. He felt that the original process selection study had been well performed and that discussion of other alternative processes were not justified. He thought the balance of the disciplines and involvement of outside personnel on the overview team (VE Team 1) was very good. He felt the VE study was an excellent opportunity for the City personnel to learn in detail how the new facility will operate and that there is probably no other way that would be comparable in effectiveness in this regard.

None of the in-house VE Team members had been involved in a prior VE study. The VE Team Coordinator had to spend some time convincing the team members that they were not repeating the normal design review procedures. A field trip by the team members to the plant under study would be worthwhile. The City Engineer felt the design personnel were helped significantly by the VE study and that the help was gratefully received.

The DEQ personnel believed that more regulatory agency input and involvement should be provided on the next VE project. They felt the perspective they have from review of all projects in the State would be useful in the VE study. They also felt that addition of personnel with construction experience to VE teams would be worthwhile. They felt the Step 1 selected process alternative should serve as a constraint on the VE process to avoid reopening aspects such as the EIS where delays could be prohibitive. A review meeting with the EPA and State prior to presenting results to the client was suggested by DEQ. The VE report should clearly spell out any risks associated with the VE recommendations.

CONCORD, N. C. PROJECT

This report is based on interviews held on November 30 and December 2, 1976 in Raleigh, N. C. and Alexandria, VA. with the design firm, the State Dept. of Environmental Management, the City, and the Value Engineer. The EPA Regional office was contacted by telephone on December 9, 1976.

Description of the Proposed Project Prior to the VE Study

A schematic of the process of the plant is shown in Figure 6. Effluent quality requirements are as follows:

BOD_5-20 mg/l	NH_3-1.0 mg/l
SS-30 mg/l	DO-80% Saturation

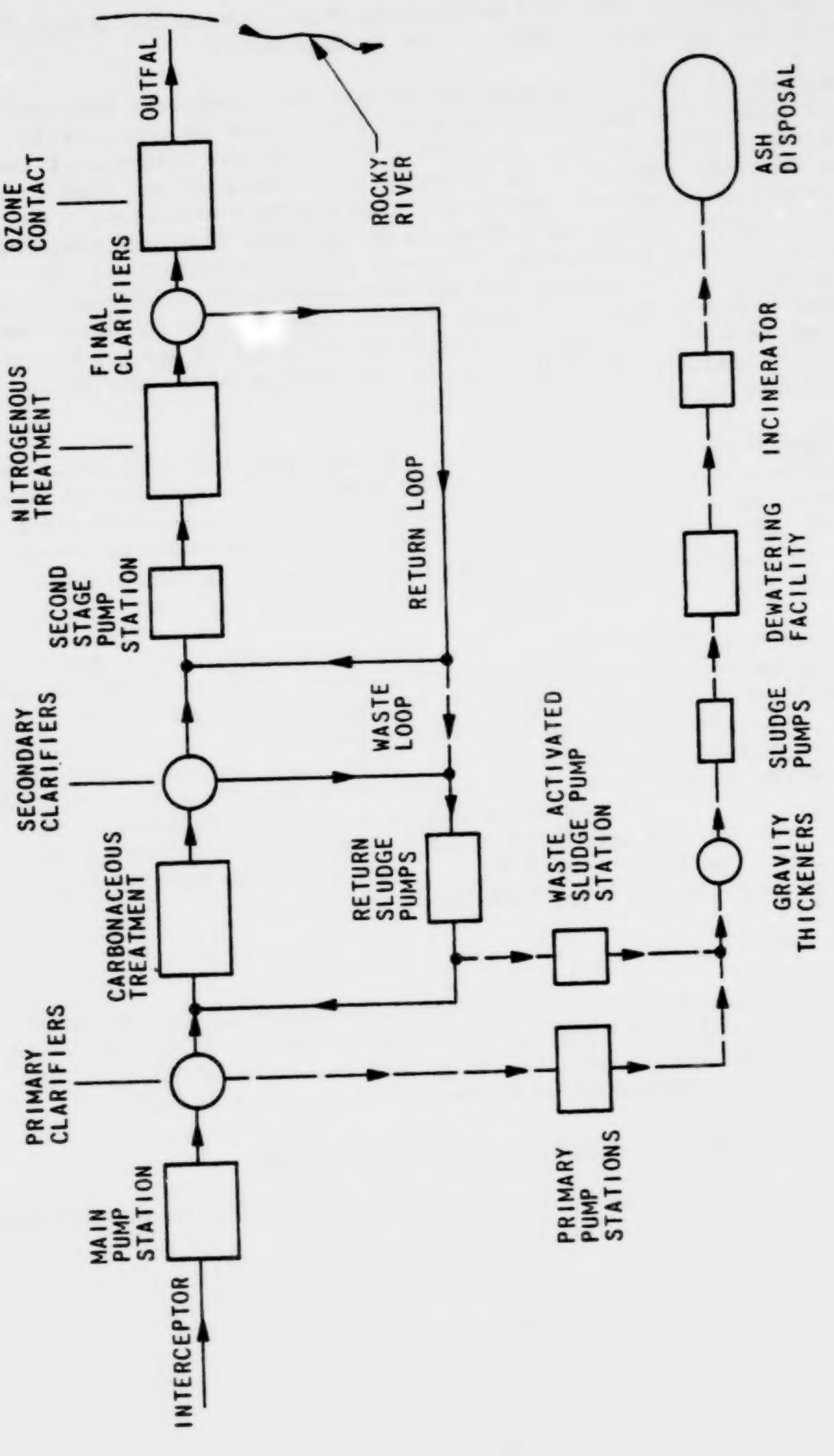

INTERCEPTOR
MAIN PUMP STATION
PRIMARY CLARIFIERS
CARBONACEOUS TREATMENT
SECONDARY CLARIFIERS
SECOND STAGE PUMP STATION
NITROGENOUS TREATMENT
FINAL CLARIFIERS
OZONE CONTACT
OUTFAL
ROCKY RIVER
RETURN LOOP
WASTE LOOP
RETURN SLUDGE PUMPS
WASTE ACTIVATED SLUDGE PUMP STATION
PRIMARY PUMP STATIONS
GRAVITY THICKENERS
SLUDGE PUMPS
DEWATERING FACILITY
INCINERATOR
ASH DISPOSAL

FIGURE 6. FLOW SCHEMATIC AS DESIGNED

The all-new facility was designed for the following flow conditions:

Average Daily Flow = 24 mgd
Maximum Daily Flow = 43.2 mgd
Peak Hourly Flow = 54 mgd
Maximum Flow Rate = 88.53 mgd
Minimum Daily Flow = 7.2 mgd

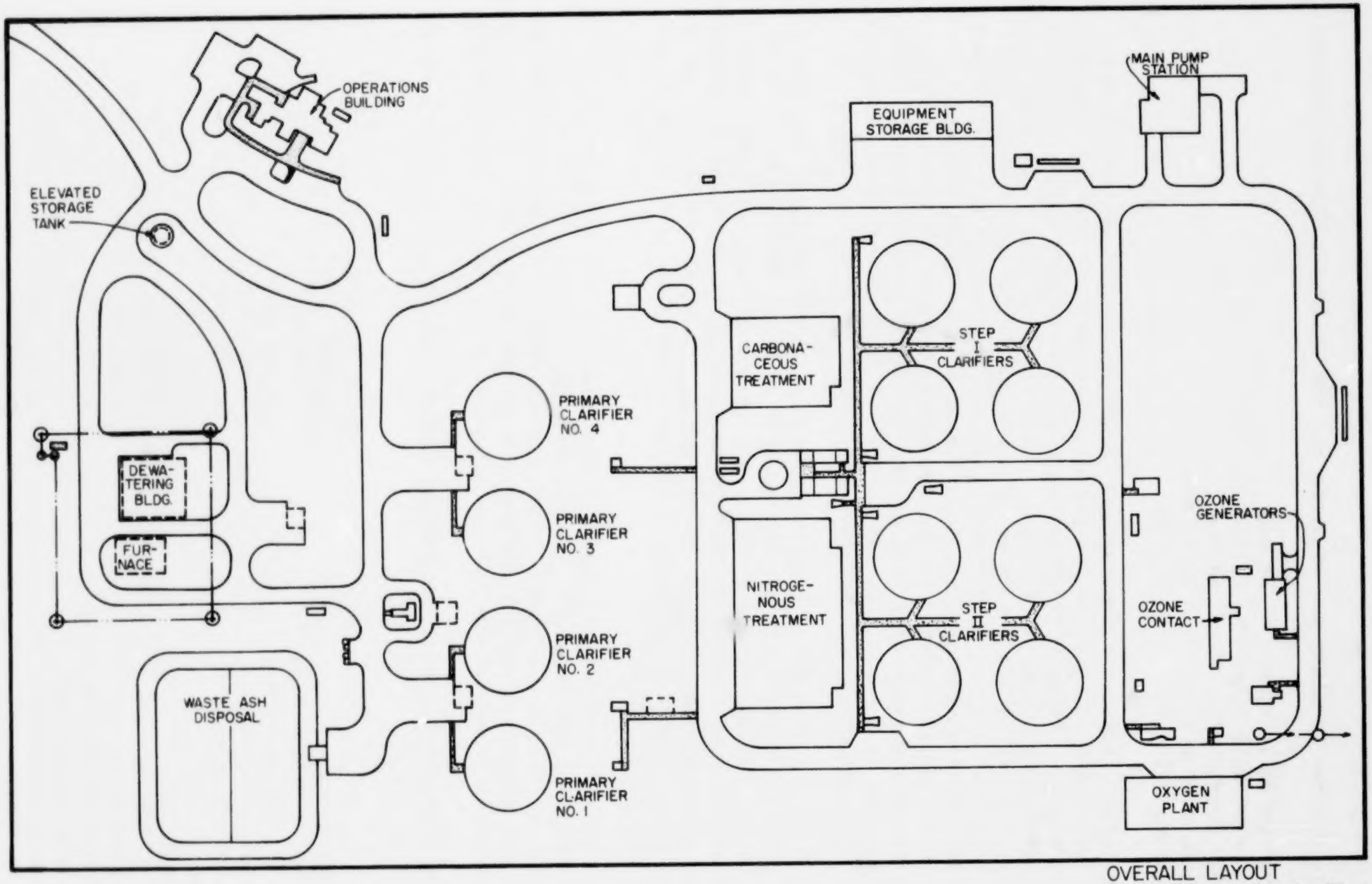
The plant receives a substantial amount of textile wastes (15 mgd initially). Lime is added to the primary clarifiers to provide removal of heavy metals. Primary treatment is followed by a pure oxygen activated sludge carbonaceous treatment basin. Once past this basin, the flow enters secondary clarifiers and passes on to the second stage pure oxygen nitrogenous treatment basin. Only flows below 1.5 x Q average enter this basin to prevent the flushing of nitrifiers during peaks. Flows in excess of this amount proceed directly to the disinfection basin and to the river. Leaving the nitrogenous treatment basin, the flow proceeds through final clarifiers and to the disinfection basin. Disinfection in this facility is handled by ozone which also provides reaeration prior to discharge.

Sludges are blended in gravity thickeners. The thickened sludge is fed to pressure filters after being blended with ash and dewatered to at least 40% dry solids. The resulting cake is burned in a multiple hearth furnace with the ash from this furnace recycled to the pressure filters for blending with incoming sludge. Excess ash is pumped in a slurry to an ash settling pond. Figure 7 presents a layout of the plant and Figure 8 presents a hydraulic profile.

The site chosen for the plant is approximately 300 acres of presently undeveloped farm and woodland. Initially, approximately 50 of the 300 acres will be directly impacted. The site is steeply sloped as evidenced by site elevations of the impacted area which range from 506' to 583' above mean sea level. Much of the site is underlain with rock at 2-10 ft depth.

The estimated cost of the project at the time of the VE study was as follows:

Components	Total Eligible Project Cost
Administration Bldg.	1,500,000
Main Pump Station	2,500,000
Aeration Basins	7,000,000
Oxygen Equipment	3,068,000
Clarifiers	5,600,000
Electrical	1,500,000
Yard Piping	2,000,000
Disinfection	1,500,000
Sludge Thickening	1,000,000
Sludge Dewatering	1,800,000
Sludge Incinerator	2,790,725
TOTAL	30,258,725


OPERATIONS BUILDING
MAIN PUMP STATION
EQUIPMENT STORAGE BLDG.
ELEVATED STORAGE TANK
CARBONA-CEOUS TREATMENT
STEP I CLARIFIERS
PRIMARY CLARIFIER NO. 4
PRIMARY CLARIFIER NO. 3
PRIMARY CLARIFIER NO. 2
PRIMARY CLARIFIER NO. 1
DEWA-TERING BLDG.
FUR-NACE
NITROGE-NOUS TREATMENT
STEP II CLARIFIERS
OZONE GENERATORS
OZONE CONTACT
WASTE ASH DISPOSAL
OXYGEN PLANT

OVERALL LAYOUT
Concord, North Carolina Plant

FIGURE 7

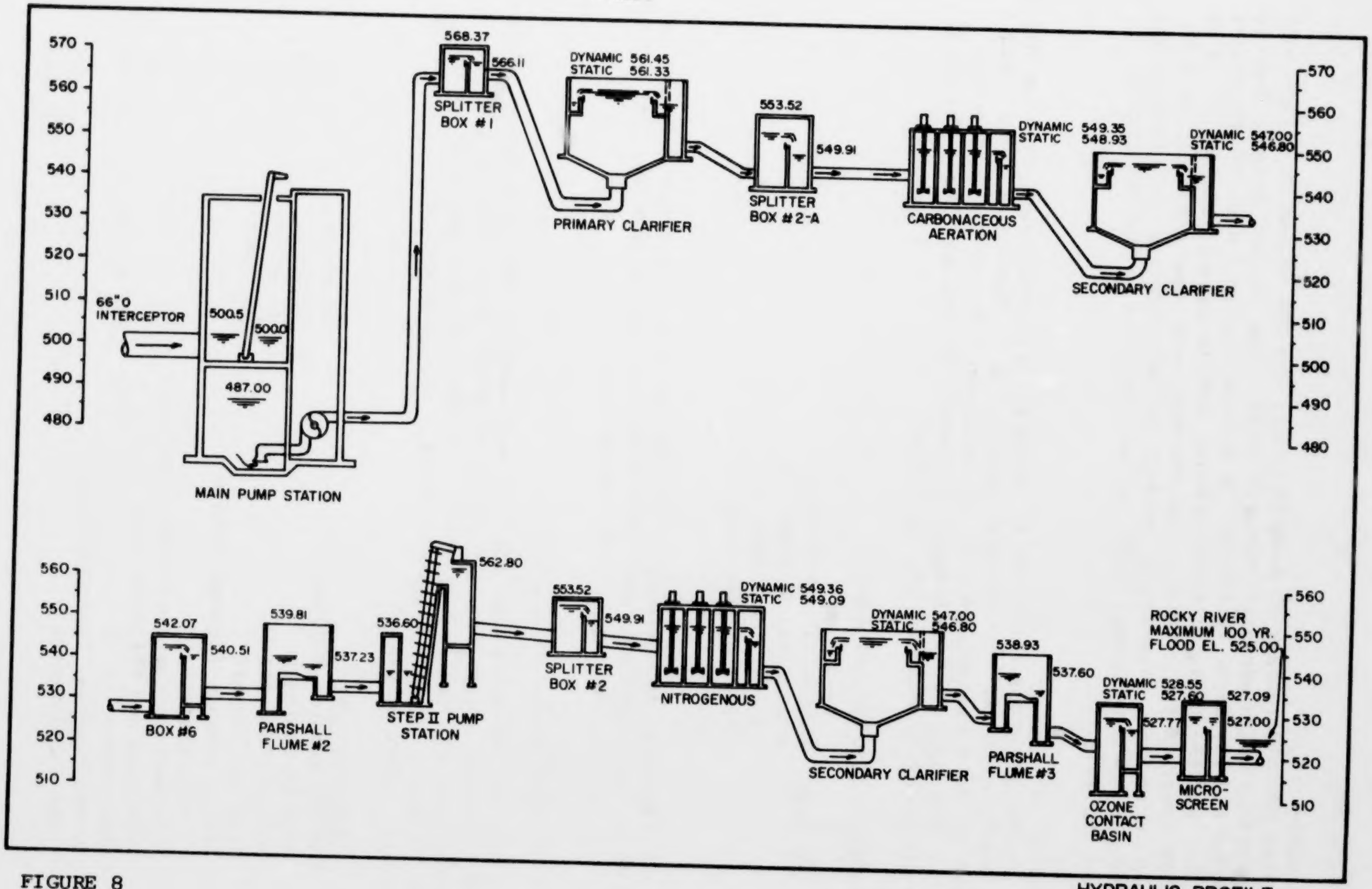

570
560
550
540
530
520
510
500
490
480
66"O INTERCEPTOR
500.5
500.0
487.00
MAIN PUMP STATION
568.37
566.11
SPLITTER BOX #1
DYNAMIC 561.45
STATIC 561.33
PRIMARY CLARIFIER
553.52
549.91
SPLITTER BOX #2-A
CARBONACEOUS AERATION
DYNAMIC 549.35
STATIC 548.93
SECONDARY CLARIFIER
DYNAMIC 547.00
STATIC 546.80
560
550
540
530
520
510
542.07
540.51
BOX #6
539.81
537.23
PARSHALL FLUME #2
536.60
562.80
STEP II PUMP STATION
553.52
549.91
SPLITTER BOX #2
NITROGENOUS
DYNAMIC 549.36
STATIC 549.09
DYNAMIC 547.00
STATIC 546.80
SECONDARY CLARIFIER
538.93
537.60
PARSHALL FLUME #3
DYNAMIC 528.55
STATIC 527.60
527.77
OZONE CONTACT BASIN
527.09
527.00
MICRO-SCREEN
ROCKY RIVER MAXIMUM 100 YR. FLOOD EL. 525.00

FIGURE 8

HYDRAULIC PROFILE
Concord, North Carolina Plant

The VE Study

Background--

When EPA's voluntary VE program began, the EPA Region IV office notified projects which appeared amenable to VE. The Concord Project Designer responded and was eager to try VE. A meeting was held with EPA personnel, the City, and the Designer in September, 1975 to discuss the merits of VE. The City endorsed the concept. The Designer sent some personnel to a VE Training Workshop. Proposal to conduct the VE Study was solicited by the Designer in early November, 1975, and was accepted by the Designer on January 12, 1976.

Organization--

The VE Study was conducted in January, 1976 at a point when the design was 70-80% complete. The Designer selected a VE Team Co-ordinator (VETC) who served as a subcontractor to the Designer. The VETC then proposed several alternate VE team members for review by the Designer. The final composition of the VE team was as follows:

VETC - CVS, BS Engineering

VE Team - Mechanical Engineer
Structural Engineer
Sanitary Engineer
Electrical Engineer
Cost Estimator

In addition, two members of the design firm were present during the entire 40-hour workshop. One was a member of the VE Team and both provided design background and history to the VE Team.

Level of VE Effort

As noted above, 1 five man team was used for the VE workshop. The total level of effort involved in the VE Study (including pre- and post-workshop effort) was 16.5 man-weeks for the VETC and Team Members and 5.25 man-weeks support by the Designer. The breakdown of effort and total costs are shown below:

Value Engineer		
Senior Program Engineer	240 hours	$ 5,500
Program Engineer	60 hours	1,070
Project Engineer	40 hours	635
Clerical Support	85 hours	580
Travel Expense (Transportation and Subsistence)		1,175
Reproduction Costs of Study Documents		930
Telephone and Shipping Costs		450
Consultants	238 hours	9,000
Travel Expense (Transportation and Subsistence)		1,460
		$20,800

Plus Designers Administrative Fee (20%) and Designers Profit (12%)		$ 7,155
SUBTOTAL		$27,955
Designer		
1. Assemble Material		
a. Print Drawings and Spec.	16 hours	
b. Cost Estimate & Documentation	60 hours	
2. Coordinate and Review documents with V.E. prior to analysis	30 hours	
3. V.E. Analysis	80 hours	
	186 hours	
Misc. Support	20 hours	
Subtotal	206 hours	6,265
TOTAL		$34,220

Consideration was given to use of a second VE Team but only one team was used because the project design was so nearly complete. Also because of the extensive design work completed, the following constraints were placed on the VE effort:

1. The process (activated sludge utilizing pure oxygen) has been fixed.
2. Effluent quality criteria are fixed.
3. Alternatives which unduly extend the design and construction period currently stipulated be de-emphasized unless there are substantial present-worth savings which would justify the delay in plant startup.
4. All alternatives must comply with all state and EPA directives, regulations, and guidelines.
5. Plant layout has been fixed.

Restrictions on project delays were important not only from the standpoint of inflationary effects but also because (1) construction grant money had to be committed in the current fiscal year and (2) a favorable situation was felt to exist for very competitive construction bids due to the recent lack of construction projects in the area.

The level of effort and constraints were accepted by the Owner, State, and EPA prior to the VE Study. The State felt that the VE effort was being made too late in Step 2 but desired to gain experience with VE. The VE Workshop was held January 26-30, 1976.

VE Study Summary

The standard cost/worth approach was used in the study. The VE Team productivity was limited on the first two days of the workshop because of uncertainity over the basic scope of the study. Some members of the VE Team wished to consider aspects of the project which apparently fell outside the original constraints (i.e., overall plant layout, process, etc.).

The cost estimates provided to the VE Team were broad and no unit quantities were available. Thus, the VE Team spent time generating unit cost data which should have been available prior to the workshop. Also, an EPA film crew was present for the first two days to gather material for a training film. This proved to be another disruptive factor.

VE Recommendations

The following is a brief description of each of the proposed changes.

1. Figure 9. Main pump station. The design had two 24 inch and two 30 inch mains. Proposed eliminating one 24 inch and one 30 inch force main. Of the two remaining mains (24 and 30 inch), changed the 24 inch to a 42 inch main.

Initial Savings	$98,050
LCC Savings (Amortized Value of Initial Savings Only)	8,700

2. Figure 9. The main pump station had two constant speed and two variable speed pumps. The VE team proposed using all variable speed pumps thereby reducing the size of wet well. Result is a reduction in size of the pump station from 70 feet by 70 feet to 70 feet by 60 feet.

Initial Savings	$221,000
LCC Annual Savings (Amortized Value of Initial Savings Only)	19,500

3. Figure 10. Main pump station. The VE team proposed constructing the lower 18 feet by excavating and utilizing the rock faces for floors and walls and using shotcreting facing. Also, decreased the excavation of site by 4.5 feet.

Initial Savings	$380,000
LCC Annual Savings (Amortized Value of Initial Savings)	33,500

4. Figure 11. Eliminated above ground enclosure over all four pump stations except for stair well enclosure.

Initial Savings	$74,000
LCC Annual Savings (Amortized Value Initial Savings)	6,520
Annual Oper. and Maint. Cost Savings	2,130

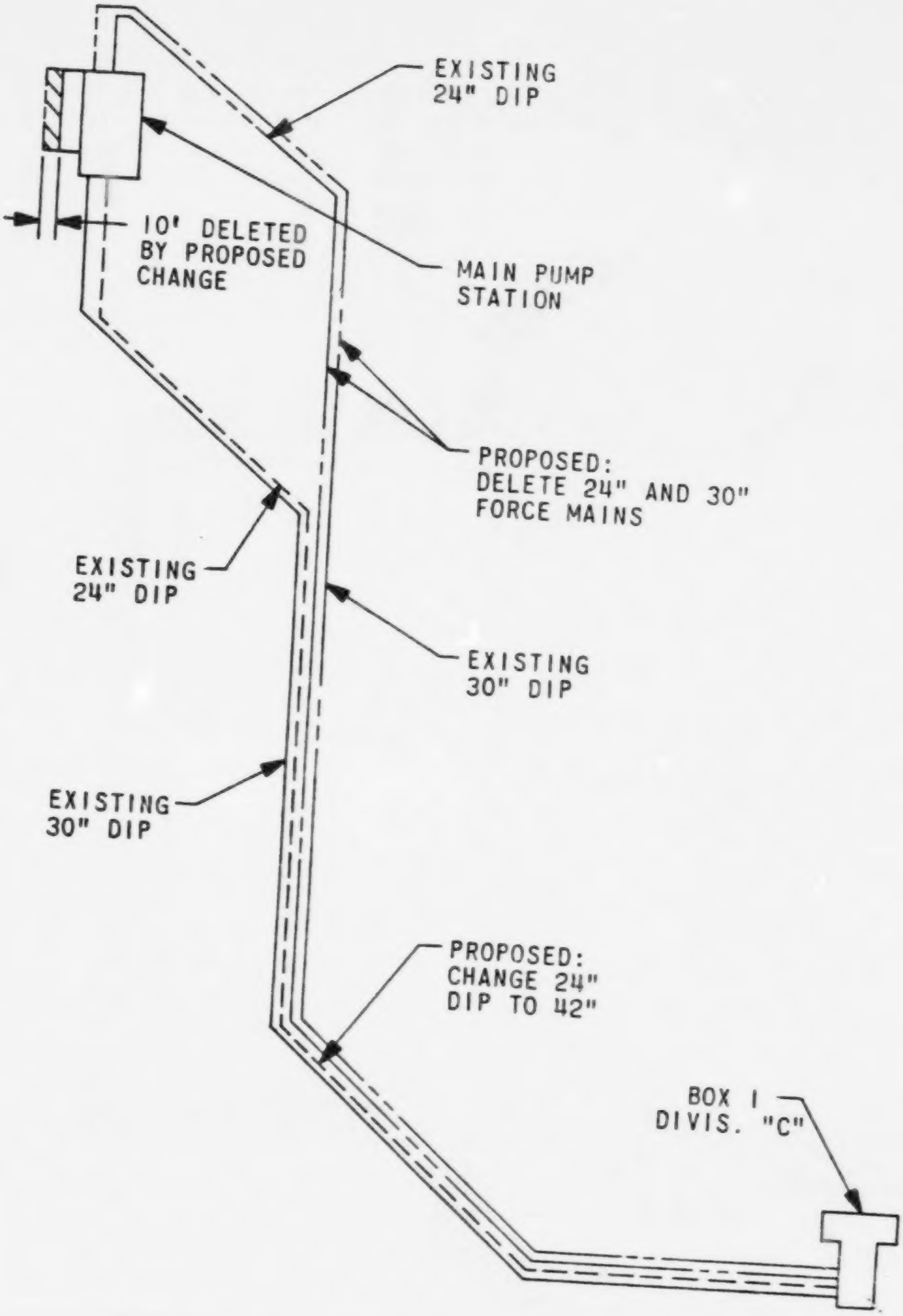

EXISTING 24" DIP
10' DELETED BY PROPOSED CHANGE
MAIN PUMP STATION
PROPOSED: DELETE 24" AND 30" FORCE MAINS
EXISTING 24" DIP
EXISTING 30" DIP
EXISTING 30" DIP
PROPOSED: CHANGE 24" DIP TO 42"
BOX 1 DIVIS. "C"

FIGURE 9. MAIN PUMP STATION & FORCE MAIN REVISION

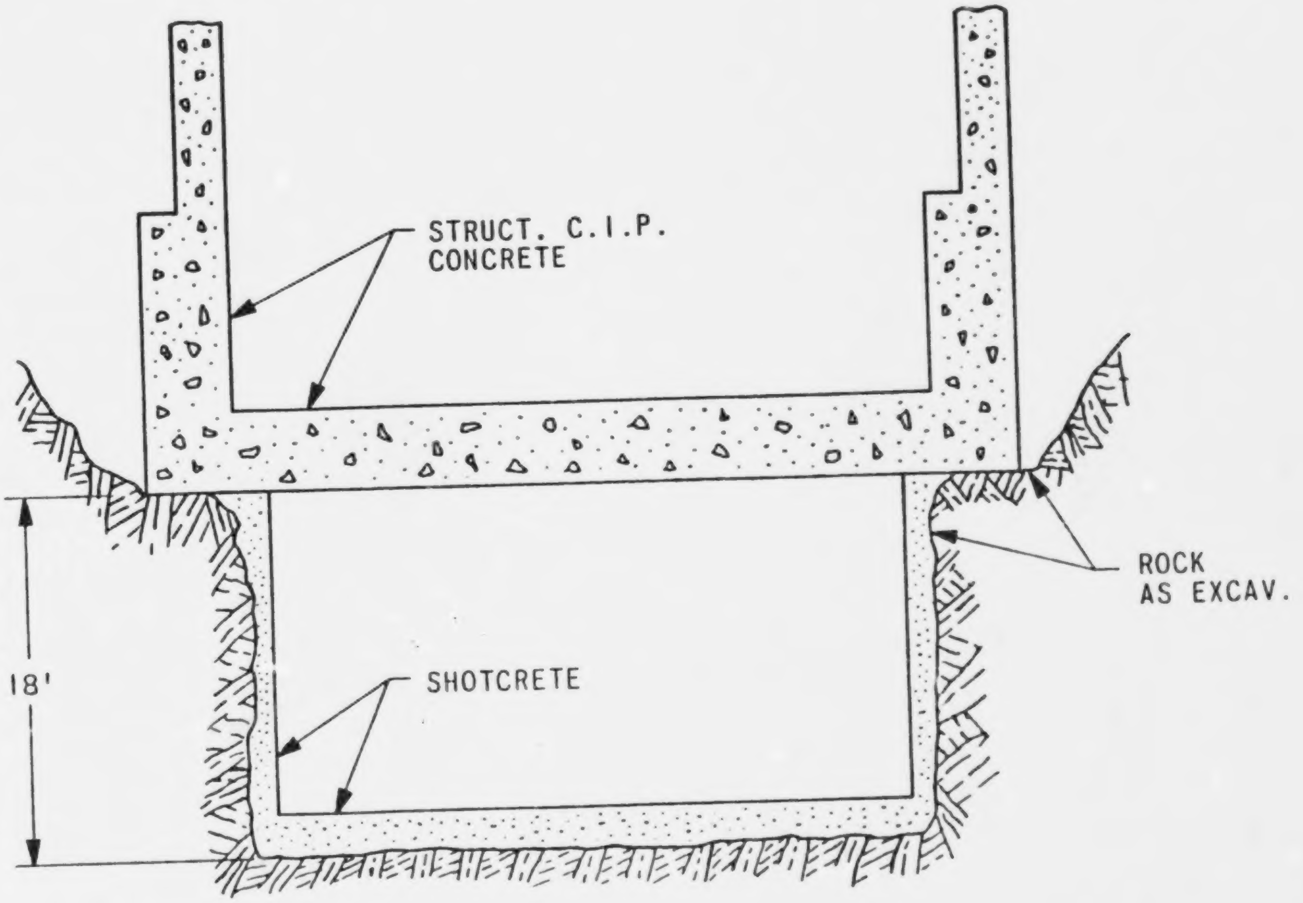
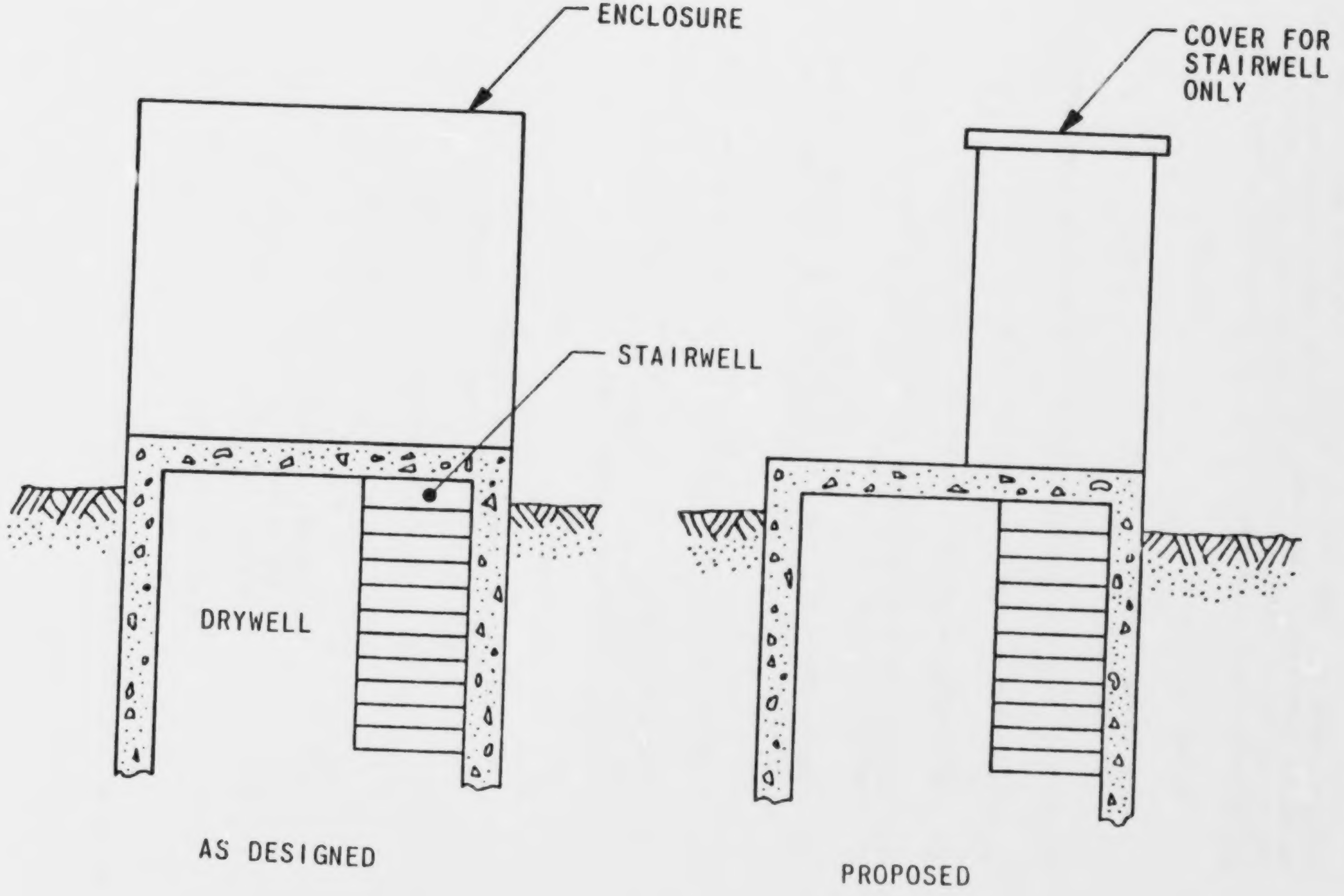

STRUCT. C.I.P.
CONCRETE
ROCK
AS EXCAV.
18'
SHOTCRETE

FIGURE 10. MAIN PUMP STATION UTILIZING ROCK FOR FOUNDATION


ENCLOSURE
STAIRWELL
DRYWELL
COVER FOR STAIRWELL ONLY

AS DESIGNED

PROPOSED

FIGURE 11. PUMP STATION ENCLOSURES

5. Figure 12 and 13. The 18 inch concrete retaining wall in the ash basin ran lengthwise. The team proposed changing the wall to run across the basin width. This would shorten the wall, road, 3 inch pipeline and electrical wiring and conduit to pump station.

Initial Savings	$95,950
LCC Annual (Amortized Value of Initial Cost Savings)	8,454

6. Figure 14. Several changes related to plant layout were proposed:

   a. Regrading to eliminate trucked-in fill.

   b. Modifying road slopes to minimize cut and fill.

   c. Change the splitter boxes and Parshall flumes to magnetic meters and flow controllers.

   d. Delete the Step II screw pump station by laying out the settling tanks and aeration tanks in concrete with the natural grade.

   e. Change the return sludge screw pumps to propeller pumps.

   f. Waste activated sludge to be pumped to gravity thickeners by branching off return sludge system and throttling a control valve to vary the flow.

Initial Savings	$3,734,170
LCC Annual Savings (Amortized Value of Initial Savings	328,000
Annual Oper. Cost Savings	30,700
Total Initial Savings	$2,974,570
LCC Annual Savings (Amortized Value of Initial Savings)	262,000
Annual Oper. Cost Savings	27,500

The total proposed savings are summarized below.

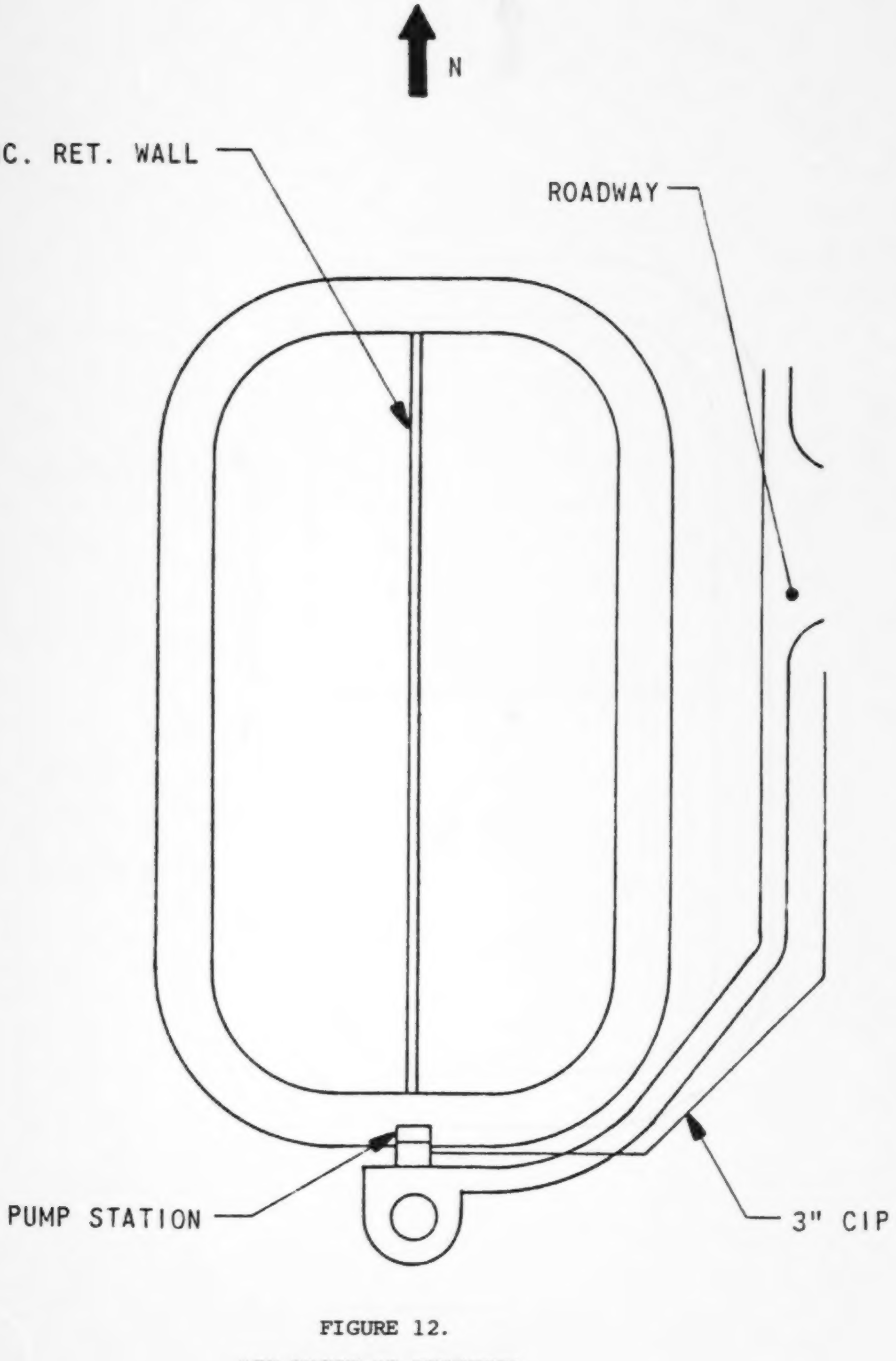

N
18" CONC. RET. WALL
ROADWAY
PUMP STATION
3" CIP

FIGURE 12.

ASH BASIN-AS DESIGNED

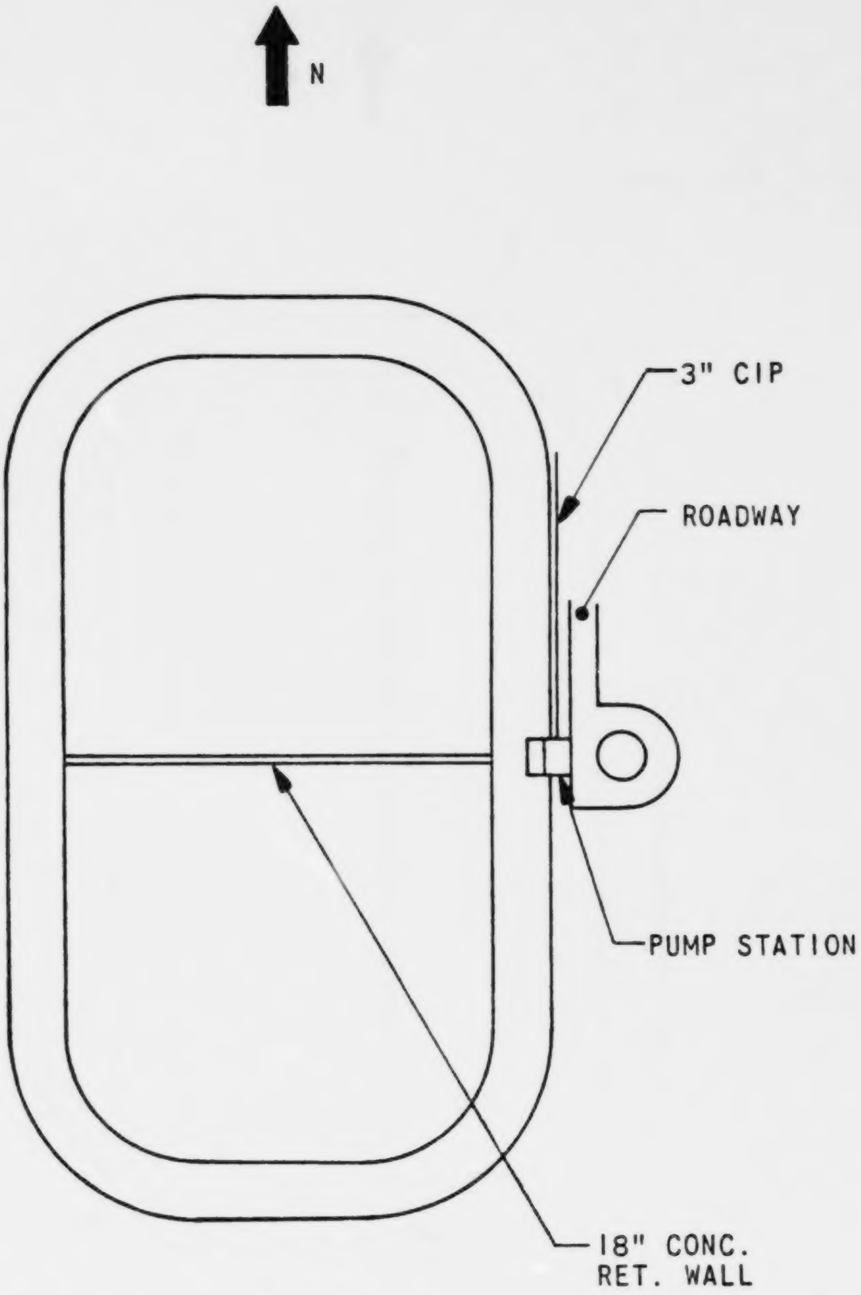

N
3" CIP
ROADWAY
PUMP STATION
18" CONC.
RET. WALL

FIGURE 13.

ASH BASIN-PROPOSED

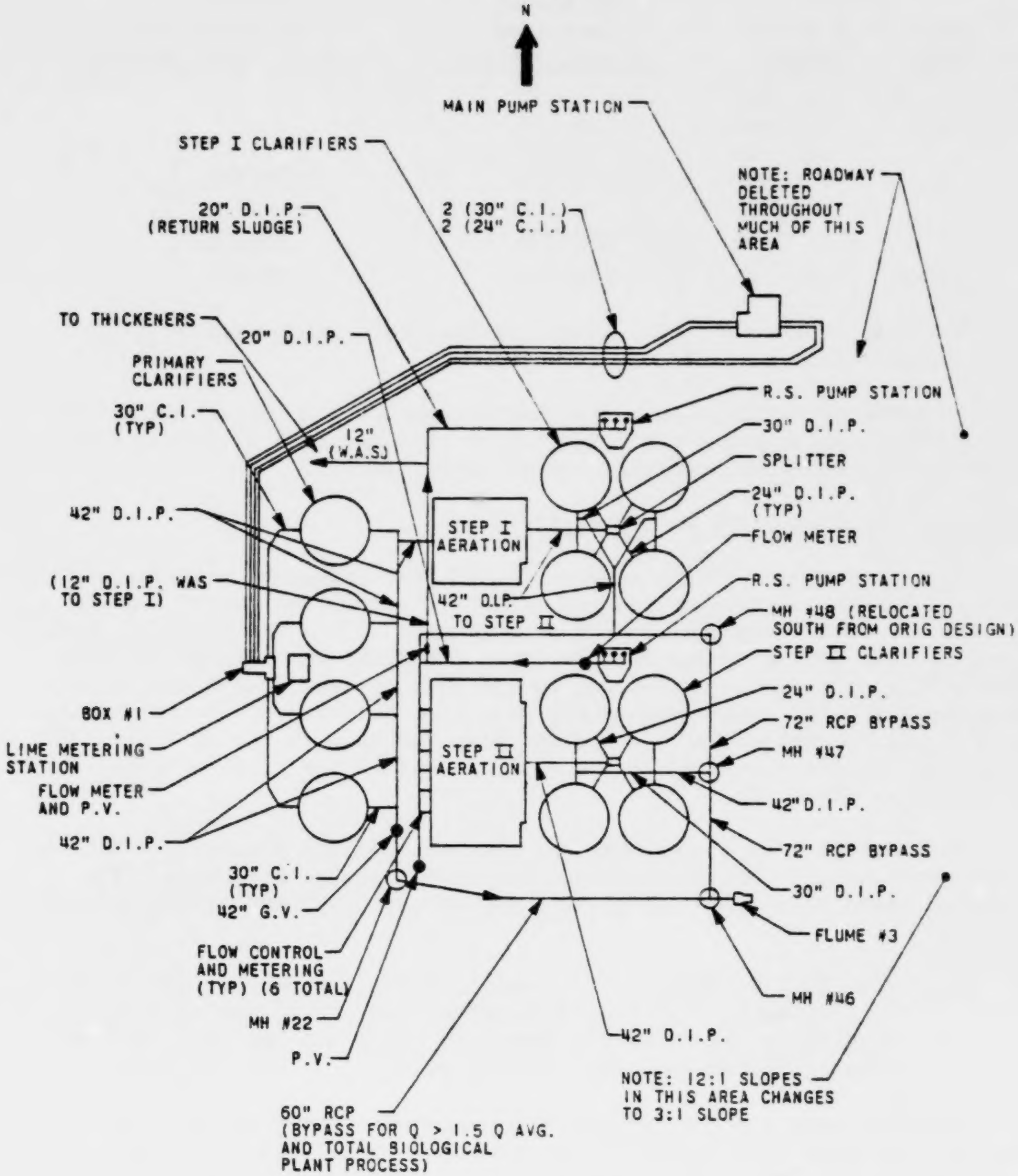

N
MAIN PUMP STATION
STEP I CLARIFIERS
NOTE: ROADWAY DELETED THROUGHOUT MUCH OF THIS AREA
20" D.I.P. (RETURN SLUDGE)
2 (30" C.I.)
2 (24" C.I.)
TO THICKENERS
20" D.I.P.
PRIMARY CLARIFIERS
R.S. PUMP STATION
30" C.I. (TYP)
12" (W.A.S.)
30" D.I.P.
SPLITTER
24" D.I.P. (TYP)
42" D.I.P.
STEP I AERATION
FLOW METER
(12" D.I.P. WAS TO STEP I)
42" D.I.P. TO STEP II
R.S. PUMP STATION
MH #48 (RELOCATED SOUTH FROM ORIG DESIGN)
STEP II CLARIFIERS
BOX #1
24" D.I.P.
72" RCP BYPASS
LIME METERING STATION
STEP II AERATION
MH #47
FLOW METER AND P.V.
42" D.I.P.
42" D.I.P.
72" RCP BYPASS
30" C.I. (TYP)
30" D.I.P.
42" G.V.
FLUME #3
FLOW CONTROL AND METERING (TYP) (6 TOTAL)
MH #46
MH #22
42" D.I.P.
P.V.
NOTE: 12:1 SLOPES IN THIS AREA CHANGES TO 3:1 SLOPE
60" RCP (BYPASS FOR Q > 1.5 Q AVG. AND TOTAL BIOLOGICAL PLANT PROCESS)

FIGURE 14. PROPOSED NEW YARD PIPING ALT. (PLANT LAYOUT AS DESIGNED)

VE Item	Initial Savings	LCC Annual (Amortized Initial Savings)	Annual Operating and Maint. Cost Savings
1.	98,050	8,700	
2.	221,000	19,500	
3.	380,000	33,500	
4.	74,000	6,520	2,130
5.	95,950	8,454	
6.	2,974,570	262,000	27,500
TOTAL	3,843,570	338,674	29,630

The life cycle cost (LCC) annual savings were calculated at 6-1/8 percent and a facility life of 20 years.

In addition to the 6 specific changes evaluated in detail by the VE Team, several other ideas were offered for consideration by the Designer. Those considered by the Designer are discussed later.

Designers Response to VE Recommendations

The Designer received a copy of the VE Team workbooks and other information including cost estimates and recommendations from the VE Team on January 31, 1976 - the day after the conclusion of the VE workshop. Every division head of the design firm reviewed the workbook together with its cost estimates and recommendations on the 31st of January and made recommendations for implementation and/or rejection for each of the recommendations. This review led to a seventeen page response to the initial draft. This response was forwarded to the VETC for his review prior to preparation of the final VE report.

Many of the initial responses of the Designer are mirrored in his formal response of March 11 to the final report summarized below. The numbered items correspond to the VE item numbers presented in the preceding section.

1. Main pump station. The original design had two 24 inch and two 30 inch mains. VE proposed eliminating one 24 inch and one 30 inch force main. Of the remaining mains (24 and 30 inch), VE changed the 24 inch to a 42 inch main.

Both of these items were thoroughly considered originally by the Designer and both were unequivocally rejected. The decision on four force mains versus two force mains, was made after consulting a pump manufacturer who had experience in dredging operations. The Designer concluded there would be a problem with settling of the larger solids which would be conveyed through the force mains at the lower flows. Also, the Designer was concerned that once a line is shut down, settling would take place and it would be very difficult to reintroduce suspension of these particles. The solution proposed was to use a high enough velocity in the line to scour the entire line upon the restarting of the pumps (velocities in the range of 8 or 9 feet per second). The Designer did not feel that such velocities would be reached with two force mains. The Designer also disagreed with a recommendation that the pumps be manifolded on a discharge header because there would be dead areas within such a header.

The Designer concluded that this VE recommendation would not give velocities adequate to eliminate grit problems and that operating and maintenance problems would be multiplied.

2. The main pump station has two constant speed and two variable speed pumps. The team proposed using all variable speed pumps thereby reducing the size of the wet well. Result is a reduction in size of the pump station from 70 feet by 70 feet to 70 feet by 60 feet.

The Designer had considered in his initial design, four variable speed pumps. He concluded that frequency control would not be available on larger pumps. Continuous running and extreme turn down on pumps would result in higher power costs than the original design. The idea was rejected.

3. Main pump station. The VE Team proposed constructing the lower 18 feet by excavating and utilizing the rock faces for floors and walls and using shotcreting facing. This also decreased the excavation of site by 4.5 feet.

Serious consideration was given to this proposal. Soil borings were made the week of February 16, 1976, in the area proposed for relocation of this station. These borings found only weathered rock initially encountered at a depth of 50 feet, well below the proposed bottom of a relocated pump station. Rock was not available for employment of this proposal and the idea was rejected.

4. Eliminate above ground enclosure over all four pump stations except for stairwell enclosure.

The pump station structures were specifically requested by the owner and served as protective cover for electrical and mechanized equipment, wash and toilet facilities, first aid kit and miscellaneous apparatus. The idea was rejected.

5. Ash Basin. The team proposed changing an 18 inch concrete retaining wall to run across the basin width rather than along its length. This would shorten the wall, road, 3 inch pipeline and electrical wiring and conduit to pump station.

This recommendation was accepted.

6. Alternatives included:

   a. Regrading to eliminate trucked-in fill.

b. Modifying road slopes to minimize cut and fill.

c. Change the splitter boxes and parshall flumes to magnetic meters and flow controllers.

d. Delete the Step II screw pump station by laying out the settling tanks and operation tanks in concrete with the natural grade.

e. Change the return sludge screw pumps to propeller pumps.

f. Waste activated sludge to be pumped to gravity thickeners by branching off return sludge system and throttling a control valve to vary the flow.

The Designers response to these recommendations was: 6a & b: Too late for such a drastic change. 6c would be nothing but operating problems. Velocity is too low for mag meter efficiency. Unbalanced flow would jeopardize a guarantee from the oxygen system supplier.

6d would require drastic rearrangement of units with increased head on main pump stations.

6e propeller pumps would destroy floc, not easily matched to flow. Also, increased operating and maintenance problems would be incurred as compared to screw pumps.

6f. This would not be as compatible with thickener operation as pump station with variable capacity and storage.

Two other ideas generated (but not fully evaluated) by the VE Team were accepted by the Designer:

Item 7: Locate lime feed system as close to application area as possible. The lime storage, preparation and feed system change was incorporated in the plans. Savings realized in this change are minimal, but operation problems are minimized with the facility being close to the high demand point.

Initial Savings	$17,500
LCC Annual (Amortized Value of Initial Savings)	1,542
Engineering cost to make change	600

Item 8: Eliminate extensive curb and gutter. Use only where necessary. Approximately 85% of curb and gutter was eliminated. Only that which was considered to be critically related to drainage, pavement protection and safety was retained.

The cost of implementing this change was significant. It was necessary to revise and recalculate a major portion of the runoff for the revised drainage system. It was necessary to revise the grading plans and re-route much of the runoff.

Initial Cost Savings	$84,796
LCC Annual (Amortized Value of Initial Savings)	7,470
Engineering cost to make change	3,200

The Designers response to the VE recommendation may be summarized as follows:

VE Item	Initial Savings	LCC Annual	Engineering Cost	
1.	Rejected	-	-	
2.	Rejected	-	-	
3.	Rejected	-	700	(to collect soil data)
4.	Rejected	-	-	
5.	95,850	8,454	800	
6.	Rejected	-	-	
Additional Items				
7.	17,500	1,542	600	
8.	84,796	7,470	3,200	
TOTAL	198,246	17,466	5,300	

The initially implemented changes had a net savings of $192,946 which represented only 5% of the savings estimated by the VE Team ($3,843,570) and 0.6% of the estimated construction cost ($30,258,725).

On April 13, 1976, the EPA Regional Office forwarded to the City a memo from EPA's Washington D.C. Municipal Construction Division. The memo questioned the basis for rejection of VE items 6d, 6e, and 6f which had an initial saving potential of $2,720,000.

This letter resulted in a meeting on May 4, 1976 in the EPA Atlanta office attended by the Designer, the City's Director of Utilities, the State of North Carolina Department of Environmental Management, the EPA Regional Office and EPA Headquarters personnel. Neither the VETC nor any of the VE Team Members attended. There was no provision in the Value Engineering contract for the VETC participation subsequent to completion of the VE report. The City supported the Designer's rejection of the VE recommendations during this meeting and EPA agreed that the Designer's response was acceptable. In addition, the Designer indicated that the total savings would be $920,000 after consideration of the VE suggestions.

The Designer supplemented his earlier response to the VE report with a letter of May 12, 1976, which expanded on his earlier grounds for rejection of VE items 6d, 6e, and 6f, and which also reported the fact that the bid was $920,000 under the Designer's estimate and that this savings was a direct result of the VE effort.

This $728,000 increase in VE savings is related to savings in clarifier costs. During the VE workshop, discussion about the potential merits of rectangular clarifiers occurred. However, no detailed evaluation of their cost was made and as can be noted from the preceeding list of VE recommendations, no change in clarifier design was proposed by the VE Study. However, the Designer elected to bid rectangular clarifiers as an alternate to the circular units (no added cost to the client for added engineering) based upon his exposure to the concept in the VE Workshop. The resulting bids indicated that the circular units were indeed lower in cost than the rectangular and the bids for the circular units were some $720,000 less than the original estimate of $5,600,000. The Designer's rationale in attributing the savings to the VE Study is (1) the thought to bid rectangular units as an alternate was inspired by the VE Workshop and (2) inclusion of the rectangular alternate led to more competitive bidding among the suppliers of circular equipment.

General Observations

The difficulty in implementing VE changes at 80% of design was very real and significant.

Confusion over constraints on the VE Scope caused inefficiencies as well as unnecessary misunderstandings among all parties.

The Designer felt the VE Team Members had inadequate experience with sewage treatment design and with VE itself. He felt too much workshop time was spent on explaining VE procedures.

The cost data provided by the Designer to the VE Team did not relate to unit quantities but was rather a general, overall estimate. The VE Team spent time generating cost data which should have been provided in advance. The Designer now intends on future VE projects to provide quantity takeoffs by the 20% design point to overcome this problem.

The VETC believes that the VETC should not be a sub-contractor to the designer in order that he can be better shielded from pressures in resolving conflicts.

Provisions should be made for VETC participation after completion of the VE report to assist in resolving differences.

The Designer became a supporter of the VE concept and has subsequent to the project study, sent 12 of his personnel to VE training workshops.

PLAINVILLE, CONNECTICUT PROJECT

This section is based on interviews and telephone conversations held during December, 1976 with the design firm, the State Department of Environmental Protection, the VE Consultant, and the municipality.

Description of the Proposed Project Prior to the VE Study

The Town of Plainville was operating a 1.6 mgd secondary treatment plant using single stage trickling filters and anaerobic digesters. Discharge of disinfected effluent is to the Pequabuck River. A flow sheet for the original plant is shown in Figure 15. Influent flows have for some time exceeded the design capacity of the plant and the effluent quality has deteriorated.

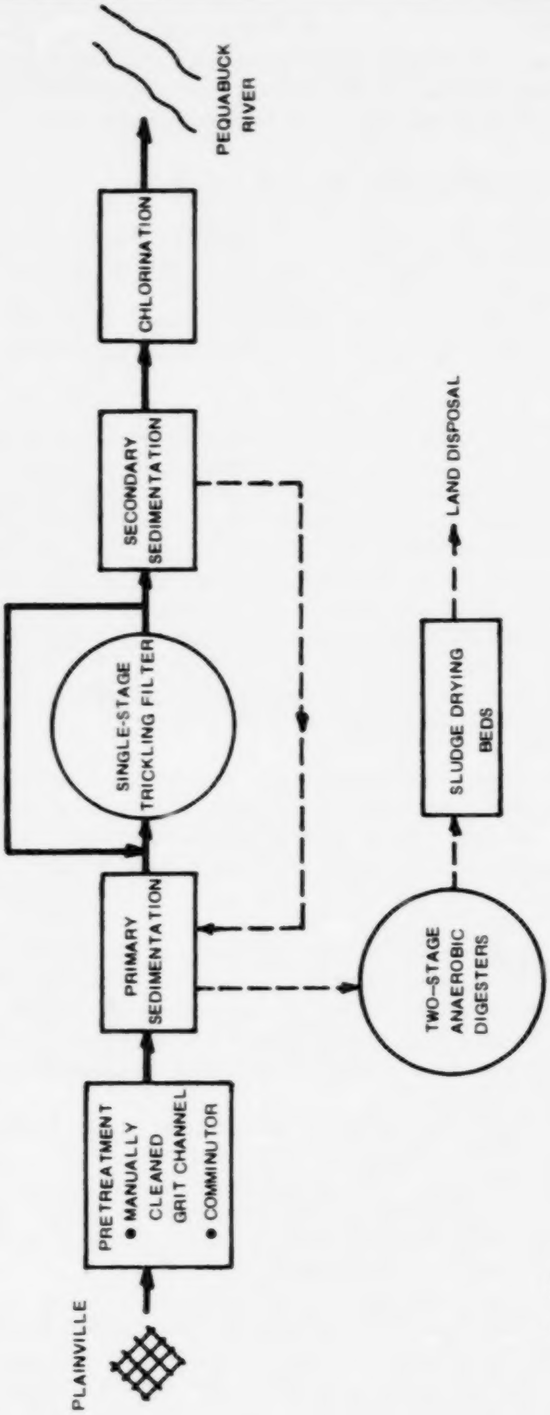
Because of the overload and more stringent discharge requirements set by the State and EPA, a series of studies were undertaken beginning in 1970 to select a treatment process and to determine the assimilative capacity of the river. These studies included operation of a pilot plant and computer modeling of the river and resulted in the final setting of discharge standards and preparation of a facilities plan in late 1974. Discharge standards are shown in Table 5. The conclusions of the studies were, that based on the influent characteristic shown in Table 6, the required effluent quality could be attained. That effluent quality corresponds to removals of approximately 95 percent of the carbonaceous oxygen demand and 92 percent of the nitrogenous oxygen demand.

To achieve the required degree of treatment, the processes described below were selected as being the most cost-effective and design was started on 3.8 mgd treatment plant. A flow sheet and a hydraulic profile for the proposed plant are shown in Figures 16A and 16B, and a site plan is shown in Figure 17.

Raw sewage entering the plant would flow to new pretreatment facilities consisting of coarse screening, grit removal in a non-aerated grit chamber, comminution, and metering. Following pretreatment, the flow would be split between the two existing and two new primary clarifiers, recombined and then pumped into new pump station to the secondary treatment system.

The proposed secondary treatment process would use four, seven-stage trains of rotating biological discs designed for removal of both carbonaceous and nitrogenous oxygen demand. The process would be housed in a heated concrete structure. The existing trickling filters would be converted to equalization basins, designed to reduce fluctuations in the load applied to the secondary and tertiary treatment.

Following secondary treatment, effluent would flow to two parallel trains of rapid mix tanks and flocculation basins. Lime, alum and polymer would be added as coagulants and settling aids in the rapid mix tanks. Biological discs would be used as flocculators.


PLAINVILLE
PRETREATMENT
• MANUALLY CLEANED GRIT CHANNEL
• COMMINUTOR
PRIMARY SEDIMENTATION
SINGLE-STAGE TRICKLING FILTER
SECONDARY SEDIMENTATION
CHLORINATION
PEQUABUCK RIVER
TWO-STAGE ANAEROBIC DIGESTERS
SLUDGE DRYING BEDS
LAND DISPOSAL

SCHEMATIC OF EXISTING STP

TOWN OF PLAINVILLE, CONN.

Figure 15

TABLE 5

DISCHARGE STANDARDS

Parameter	Effluent (mg/l) w/Filtration	Effluent (mg/l) w/Filtration and Chemical Clarification
BOD	5	2
Suspended Solids	10	1
Ammonia (as N)	2	2
Phosphorus (as P)	14 (7)*	2 (1)*
Ultimate Oxygen Demand	17	12

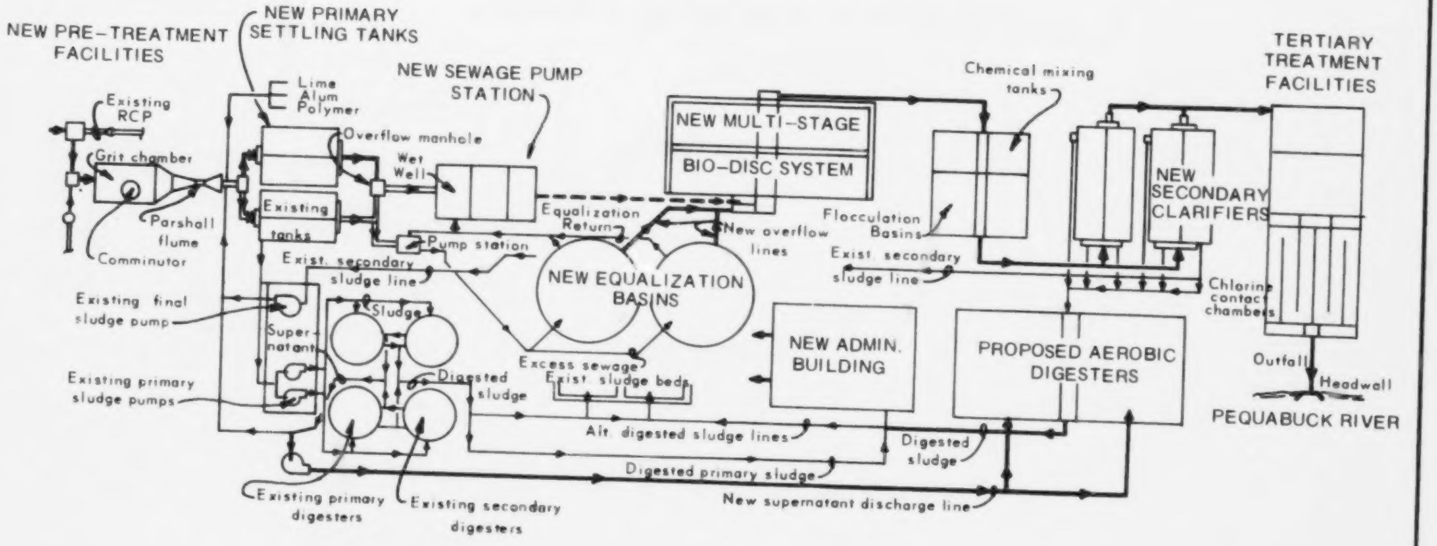
*Value in parentheses indicates expected level with industrial discharge restrictions.

TABLE 6

DESIGN CRITERIA AND INFLUENT CHARACTERISTICS

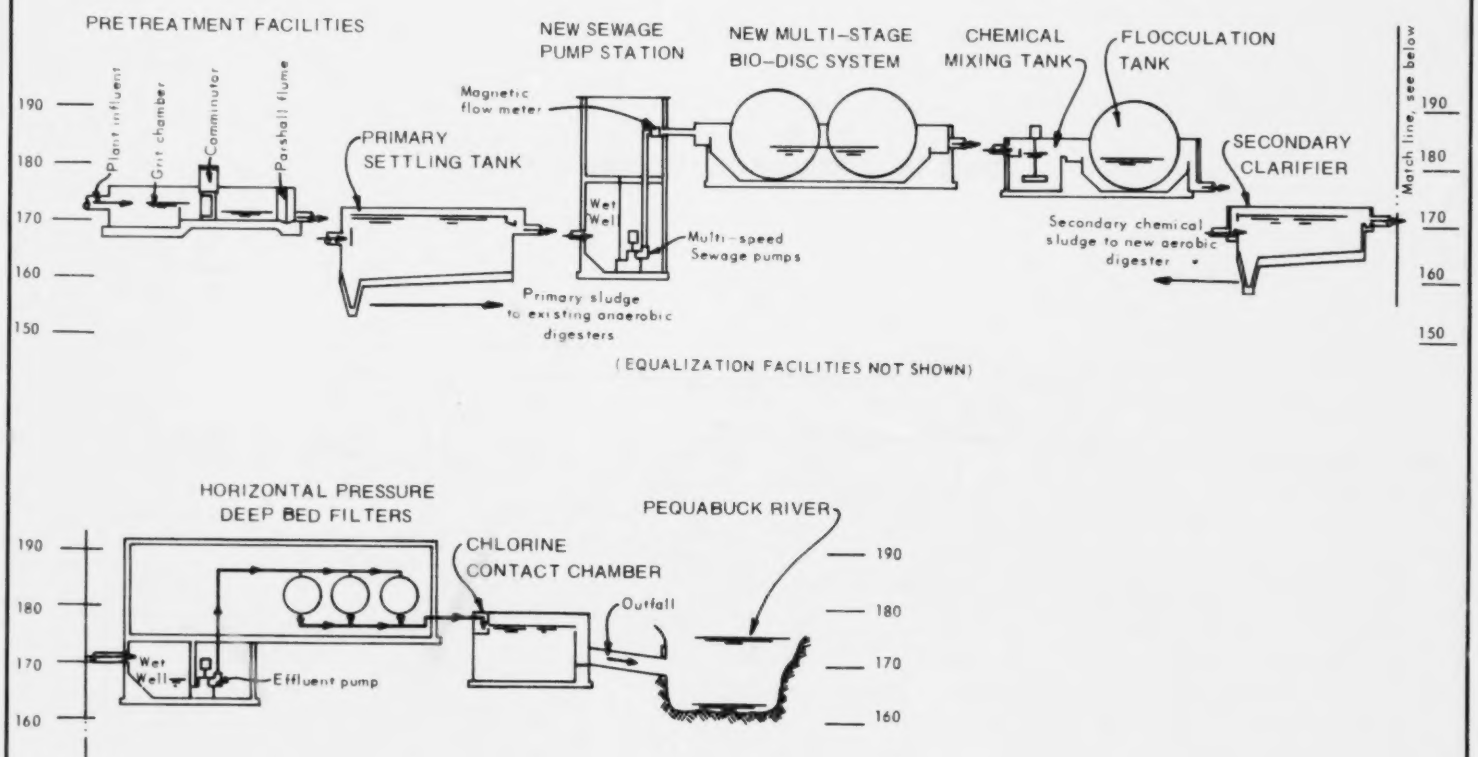
Design Parameter	Value
Life	25 yr (1975 to 2000)
Flow	
Avg	3.8 mgd
Peak	9.9 mgd
Influent	
BOD	180 mg/l
Suspended Solids	200 mg/l
Ammonia (as N)	22 mg/l
Phosphorus (as P)	20 (10)* mg/l
Ultimate Oxygen Demand	371 mg/l

*Value in parentheses indicates expected level with industrial discharge restrictions.


NEW PRE-TREATMENT FACILITIES
NEW PRIMARY SETTLING TANKS
NEW SEWAGE PUMP STATION
Existing RCP
Grit chamber
Parshall flume
Comminutor
Lime
Alum
Polymer
Overflow manhole
Wet Well
Existing tanks
Pump station
Exist. secondary sludge line
Existing final sludge pump
Existing primary sludge pumps
Super-natant
Sludge
Digested sludge
Existing primary digesters
Existing secondary digesters
NEW MULTI-STAGE
BIO-DISC SYSTEM
Equalization Return
New overflow lines
NEW EQUALIZATION BASINS
Excess sewage
Exist. sludge beds
Alt. digested sludge lines
Digested primary sludge
New supernatant discharge line
NEW ADMIN. BUILDING
Chemical mixing tanks
Flocculation Basins
Exist. secondary sludge line
PROPOSED AEROBIC DIGESTERS
Digested sludge
NEW SECONDARY CLARIFIERS
Chlorine contact chambers
TERTIARY TREATMENT FACILITIES
Outfall
Headwall
PEQUABUCK RIVER

SCHEMATIC FLOW DIAGRAM PRIOR TO VE STUDY

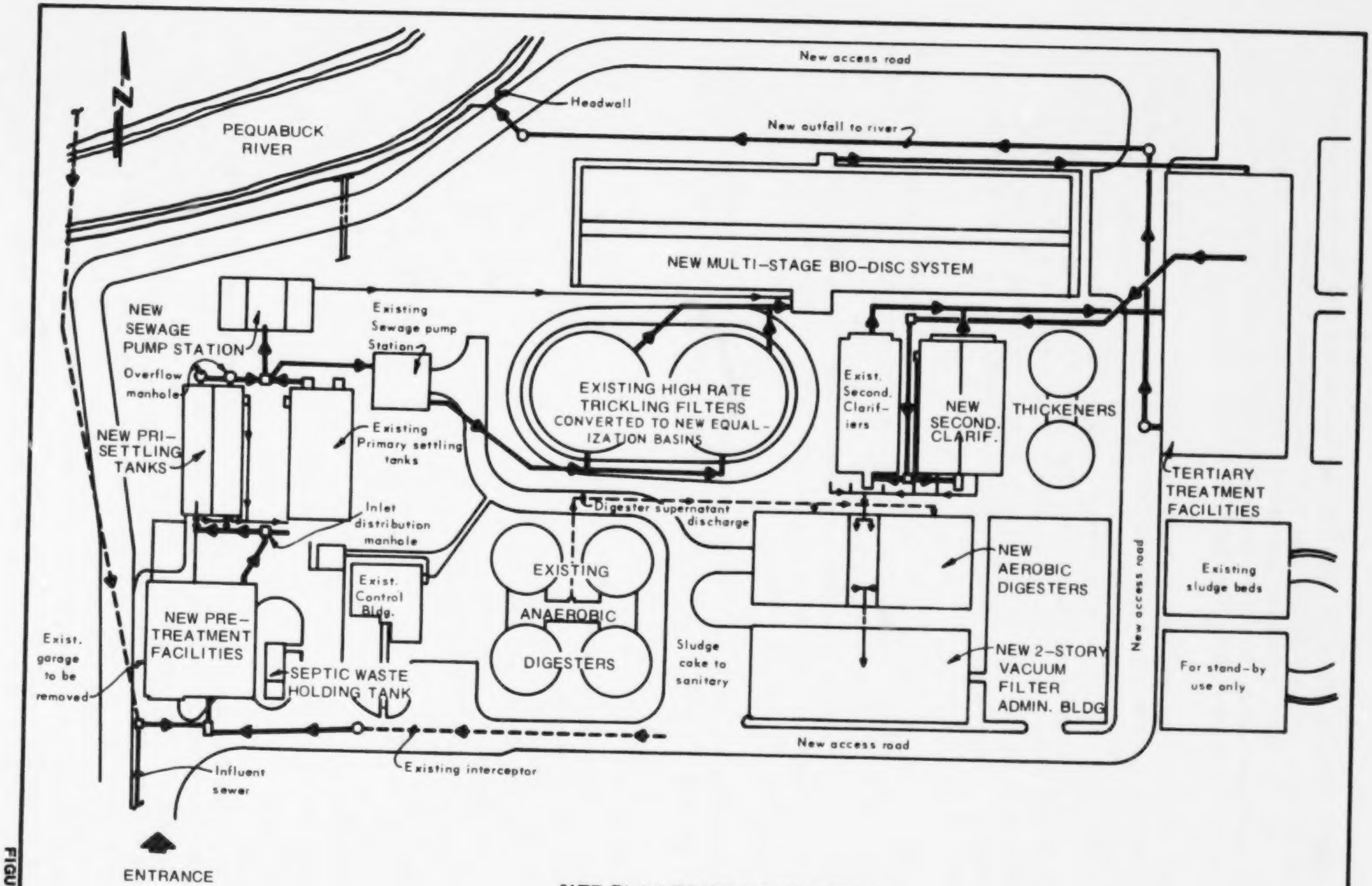
FIGURE 16A



PRETREATMENT FACILITIES
Plant influent
Grit chamber
Comminutor
Parshall flume
PRIMARY SETTLING TANK
Primary sludge to existing anaerobic digesters
NEW SEWAGE PUMP STATION
Magnetic flow meter
Wet Well
Multi-speed Sewage pumps
NEW MULTI-STAGE BIO-DISC SYSTEM
CHEMICAL MIXING TANK
FLOCCULATION TANK
SECONDARY CLARIFIER
Secondary chemical sludge to new aerobic digester
Match line, see below
190
180
170
160
150
(EQUALIZATION FACILITIES NOT SHOWN)
HORIZONTAL PRESSURE DEEP BED FILTERS
Wet Well
Effluent pump
CHLORINE CONTACT CHAMBER
Outfall
PEQUABUCK RIVER
Match line See above

HYDRAULIC PROFILE PRIOR TO VE STUDY

FIGURE 16B


PEQUABUCK RIVER
N
Headwall
New access road
New outfall to river
NEW MULTI-STAGE BIO-DISC SYSTEM
NEW SEWAGE PUMP STATION
Overflow manhole
NEW PRI-SETTLING TANKS
Existing Sewage pump Station
Existing Primary settling tanks
Inlet distribution manhole
EXISTING HIGH RATE TRICKLING FILTERS CONVERTED TO NEW EQUALIZATION BASINS
Exist. Second. Clarifiers
NEW SECOND. CLARIF.
THICKENERS
TERTIARY TREATMENT FACILITIES
Digester supernatant discharge
EXISTING ANAEROBIC DIGESTERS
Exist. Control Bldg.
NEW PRE-TREATMENT FACILITIES
SEPTIC WASTE HOLDING TANK
Exist. garage to be removed
Sludge cake to sanitary
NEW AEROBIC DIGESTERS
NEW 2-STORY VACUUM FILTER ADMIN. BLDG
New access road
Existing sludge beds
For stand-by use only
New access road
Existing interceptor
Influent sewer
ENTRANCE

SITE PLAN PRIOR TO VE STUDY

FIGURE 17

From there, effluent would flow to two existing and two new chemical/secondary clarifiers for settling and then be pumped through three, new, multi-media, horizontal, pressure filters. After filtration, the effluent would be disinfected with chlorine and subjected to post aeration in a new chlorine contact tank and then discharged to the river.

The two sludge streams would be treated separately. Primary sludge would be digested in the two existing two-stage, heated, anaerobic digesters. Additional insulation would be installed on the digesters to make them more efficient. Secondary/tertiary sludge would be digested in two new aerobic digesters, thickened in two new gravity thickeners and then combined with the digested primary sludge. The combined sludge would then be dewatered on two new vacuum filters and hauled by truck to the town's landfill. Existing sludge drying beds would remain in service for standby use.

In addition to the described treatment facilities, the design also included a 2-story administration building housing offices and a laboratory; a building covering the chemical treatment system and filters as well as additional office, locker room and lab facilities; a building housing the dewatering equipment; a building housing the pretreatment system; and 1200 linear feet of influent sewer.

The construction cost for the facilities based on first quarter 1976 prices was estimated to be $7,550,000. A breakdown of the costs is shown below:

Sitework	$ 784,200
Primary and pre-treatment	478,400
Secondary treatment	2,224,900
Tertiary treatment	
Chemical feed, mix and floc	268,700
Filtration	556,400
Disinfection-post aeration	53,600
Clarification	264,200
Sludge handling	988,800
Interface	792,700
Buildings	1,146,400

The VE Study

Background--

After attending an AIA-ACEC instructional workshop on value engineering, the designer was convinced of the merits of VE and was anxious to apply it to one of his projects. Costs for the Plainville project were escalating and it was thought that good opportunity existed to achieve some savings through VE. At the time EPA was looking for projects on which VE studies could be conducted on a voluntary basis and, when approached by the designer, recommended the project. The designer then discussed VE and its potential with the town's staff and together they convinced the Town Council to apply for funding of a VE study. The State DEP approved the VE concept. The regional EPA office authorized an amendment to the Step 2 grant.

Organization--

The VE study was conducted in two workshops. The first workshop was held in June and July of 1975 when design was approximately 15 percent complete. This workshop used five teams and involved a review of the process as well as the physical design. The second workshop was conducted in October of 1975 when the project was approximately 75 percent complete. This workshop used three teams and concentrated more on operation and maintenance aspects of the project.

The name given, basic function addressed, and responsibilities assigned to each team were as follows:

Workshop I

Team 1 - Site
Basic function - Provide access

Responsibilities - Maintain operation of access to and around the existing plant during construction; review alternatives for providing security, lighting, landscaping and flood protection and review consolidation of processes and buildings on the site.

Team 2 - Energy
Basic function - Provide energy

Responsibilities - Review means for reducing and conserving process, building, and site energy; reduce number of pumping stages; review choice of energy sources.

Team 3 - Process
Basic function - Treat waste

Responsibilities - Consolidate processes, reduce pumping stages, maximize and integrate the use of existing facilities and processes with new processes, review life cycle costs for processes, improve aesthetics of plant.

Team 4 - Buildings
Basic function - Enclose spaces

Responsibilities - Minimize the amount of enclosed space; consolidate buildings for processes, administration and laboratory to reduce life cycle cost; review use of alternative building systems and materials.

Team 5 - Underground Structures
Basic function - Support process

Responsibilities - Review design of concrete tanks, foundations and other UG structures; review design techniques and criteria; and review plant layout and configuration of structures.

Workshop II

Team 1 - Site
Basic function - Provide access

Responsibilities - Maintenance of operation during construction. Look at alternatives for providing security, landscaping, paving and interfacing.

Team 2 - Buildings
Basic function - Enclose spaces

Responsibilities - Minimize building volumes and excavation and dewatering costs. Look into alternatives for building finishes, structural systems and equipment placement.

Team 3 - Maintenance/Operation/Replacement (MOR)
Basic function - Maintain treatment

Responsibilities - Minimize costs for MOR. Look for alternatives which reduce costs for labor, chemicals, electrical energy, fuel parts, and equipment replacement.

The workshops were conducted along the same lines as the AIA/ACEC instructional workshops and as such served the dual functions of training and value engineering. The designer retained a VE consultant to lead the workshops and provide the instruction.

Members of the teams were selected largely from the designer's staff but included personnel from the Town of Plainville, the State Department of Environmental Protection and elsewhere as indicated below. During the first workshop, personnel actually working on the design were used as team members as it was thought that at that point the design had not become sufficiently "fixed" to hinder their objectivity. Conversely, it was thought that the designers had the best knowledge of the project and, therefore, could perform most effectively. Many of the individuals who had done the original design work were no longer with the design firm. Thus, the personnel who were involved in the VE study were not those responsible for the original design decisions.

During the second workshop more team members from outside the designer's office were used and fewer of the designer's personnel directly involved with the design were used. For this later workshop it was felt that a more beneficial study could be conducted by using people more familiar with the construction, operation, and maintenance of treatment facilities. It was also felt that by this point the designers might not be as objective or creative as they should be about reviewing and changing their own work.

For the most part, teams were multidisciplinary and were composed as shown:

Workshop I

Team 1 - Site
Electrical Engineer (Designer) Team Leader
Mechanical Engineer (Designer)
Civil Engineer (Designer)
Landscape Architect (Designer)
Supt. of Public Works (Plainville)

Team 2 - Energy
2 Mechanical Engineers (Designer) one was Team Leader
Electrical Engineer (Designer)
Civil Engineer (Designer)
Plumbing Engineer (Designer)
Town Manager (Plainville)

Team 3 - Process
2 Environmental Engineers (Designer) one was Team Leader
Chemist (Designer)
Sanitary Engineer (State)
Treatment Plant Superintendent (Plainville)

Team 4 - Buildings
Planner/Architect (Designer) Team Leader
Architect (Designer)
2 Building Designers (Designer)

Team 5 - Underground Structures
3 Structural Engineers (Designer) one was Team Leader
Technical Writer (Designer)

Workshop II

Team 1 - Site
Landscape Designer (Designer) Team Leader
Plumbing Engineer (Designer)
Contractor (Consultant)
Field Engineer (Designer)
Electrical Designer (Designer)

Team 2 - Buildings
Architect (Consultant) Team Leader
Structural Engineer (Designer)
Electrical Engineer (Designer)
Mechanical Engineer (Designer)
Treatment Plant Superintendent (Plainville)

Team 3 - Maintenance, Operation and Replacement
3 Environmental Engineers (Designer) one was Team Leader
Treatment Plant Supervisor (Plainville)
Sanitary Engineer (State)

Level of Effort

As discussed above, the VE study was conducted in two parts, the first consisting of a five-team workshop at the 15 percent completion point, and the second a three team workshop at the 75 percent completion point. Both workshops were forty hour sessions and were preceeded by information gathering and preparation work and followed by the preparation of a report and the presentation of results. This level of effort was considered appropriate and close to optimum for the size and type of project involved by the participants who believed that a fewer number of teams would not have been able to cover the selected subjects adequately. Also, the VE effort was used for training of the designer's staff in VE techniques which may have influenced the number of personnel involved.

The grant-eligible cost for the complete VE study was $53,610. This cost was considerably below the amount spent by the designer, however, because the workshops were used as training sessions and not all costs were eligible for grant funding. Costs for travel and subsistance were small since most of the team members either were on the designer's staff or were from the immediate area.

None of the often-found constraints, except that the workshops must not delay the overall project, were applied to the study. To the contrary, review of the process and equipment selection was encouraged. It was commented that "process selection" exerts the greatest influence on the overall project cost and therefore, it is the area having the greatest potential for savings.

Method Used For The VE Study

Before beginning the first workshop, meetings were held between the designer and the VE consultant to plan the study, set the number and makeup of the teams and assign topics to each team. Also during this planning period, a cost estimate was prepared and materials to be used in the study were collected and reviewed.

The workshops were divided into four phases typical of conventional VE studies. These phases were: information, speculative or creative, analytical or evaluation, and recommendation.

The emphasis of the information phase was to acquaint all team members with the project, plans, specifications, project reports, costs and other available documents. Because workshops were instructional as well as problem solving sessions, this first phase also was used to explain VE to the team members. For the first workshop, the session for this phase was held on one day about two weeks before the other four day session.

The information phase resulted in the completion of functional analyses and the preparation of cost models. Examples of these are shown in Figures 18-20 for the first workshop and Figures 21-23 for the second workshop. F.A.S.T. diagrams were used as aids to determining the basic functions to consider. Worths used in the cost models were determined from the lowest costs to reasonably meet the basic functions.

In the period between the two sessions, additional information was collected. Because there was already some idea of what alternatives might be proposed and analysed at the later session, additional costs relating to those alternatives were gathered and estimated during this interim period.

The workshop continued with the speculative phase. This phase used the brain-storming technique to generate ideas for study during the analytical phase. Some 250 ideas were generated during the first workshop and after preliminary review, about 40 percent of these ideas were passed on to the analytical phase for further evaluation. In the second workshop, the three teams listed approximately 110 ideas about 30 percent of which were passed on for evaluation.

The procedure used for evaluation involved first listing the advantages and disadvantages of the best ideas carried over from the speculative phase and then ranking the ideas to narrow the number passed on for further evaluation. Each of the surviving ideas was then compared against the present design on an "Analysis Matrix." Here, the important criteria for the particular functions were listed across the page and weighting factors reflecting their relative importances were given. A ranking was then assigned for each alternative and criteria and total values reflecting the merits of the alternatives were determined. A criteria weighting process comparing the importance of assigned criteria and finally arriving at a relative weight for each criterion was employed to help set the weighting factors used in the analysis matrix. Completed samples of the several forms used in the evaluation phase are included as Figures 24, 25, and 26.

To complete the evaluation phase, construction costs and then life cycle costs were estimated for each alternative scoring high on the analysis matrix.

Finally, a value engineering recommendation was prepared by each team. Alternatives showing the greatest cost savings were presented along with a summary of the design criteria and a listing of before and after construction and life cycle costs.

These proposals along with an overall summary of savings were presented to the Town Council and the State DEP in a formal meeting at the end of each workshop. Following the presentations, final reports giving all data and summaries were prepared and submitted to the Town, State and EPA.

Results and Recommendations of the VE Study

The savings in initial costs as a result of the VE Study were estimated

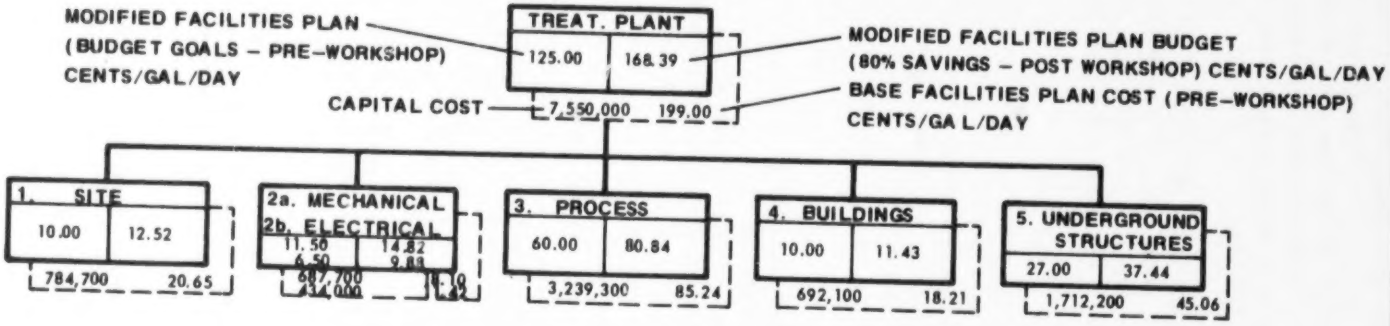
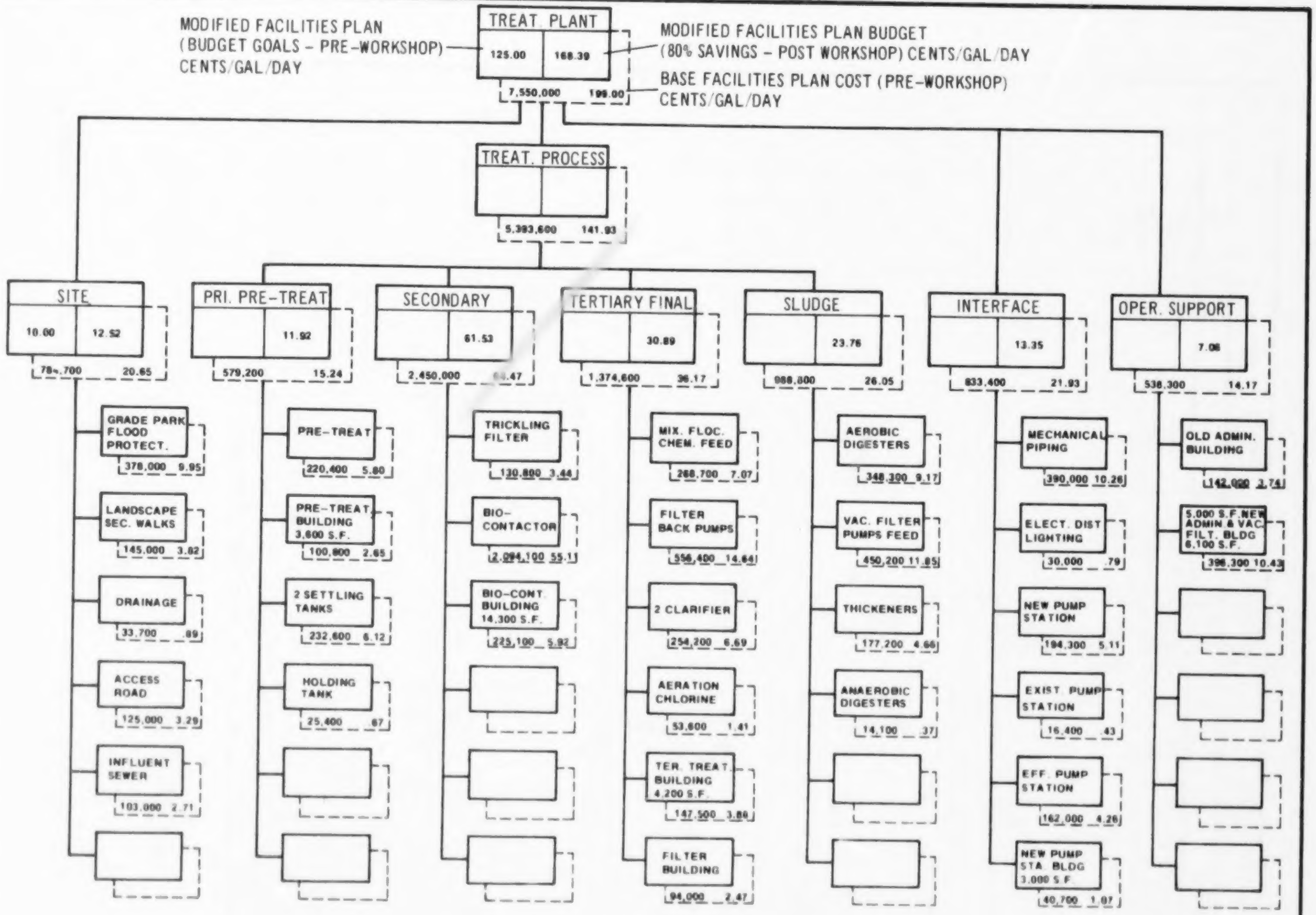

MODIFIED FACILITIES PLAN
(BUDGET GOALS – PRE–WORKSHOP)
CENTS/GAL/DAY
CAPITAL COST
TREAT. PLANT
125.00
168.39
7,550,000
199.00
MODIFIED FACILITIES PLAN BUDGET
(80% SAVINGS – POST WORKSHOP) CENTS/GAL/DAY
BASE FACILITIES PLAN COST (PRE–WORKSHOP)
CENTS/GAL/DAY
1. SITE
10.00
12.52
784,700
20.65
2a. MECHANICAL
2b. ELECTRICAL
11.50
6.50
14.82
9.88
687,700
434,000
3. PROCESS
60.00
80.84
3,239,300
85.24
4. BUILDINGS
10.00
11.43
692,100
18.21
5. UNDERGROUND STRUCTURES
27.00
37.44
1,712,200
45.06

FIGURE 18.
COST MODEL – WORKSHOP NO. 1 TEAMS


MODIFIED FACILITIES PLAN
(BUDGET GOALS – PRE-WORKSHOP)
CENTS/GAL/DAY
TREAT. PLANT
125.00
168.39
7,550,000
199.00
MODIFIED FACILITIES PLAN BUDGET
(80% SAVINGS – POST WORKSHOP) CENTS/GAL/DAY
BASE FACILITIES PLAN COST (PRE-WORKSHOP)
CENTS/GAL/DAY
TREAT. PROCESS
5,393,600
141.93
SITE
10.00
12.52
784,700
20.65
PRI. PRE-TREAT
11.92
579,200
15.24
SECONDARY
61.53
2,450,000
64.47
TERTIARY FINAL
30.89
1,374,600
36.17
SLUDGE
23.76
988,800
26.05
INTERFACE
13.35
833,400
21.93
OPER. SUPPORT
7.08
538,300
14.17
GRADE PARK FLOOD PROTECT.
378,000
9.95
LANDSCAPE SEC. WALKS
145,000
3.82
DRAINAGE
33,700
.89
ACCESS ROAD
125,000
3.29
INFLUENT SEWER
103,000
2.71
PRE-TREAT
220,400
5.80
PRE-TREAT BUILDING 3,600 S.F.
100,800
2.65
2 SETTLING TANKS
232,600
6.12
HOLDING TANK
25,400
.67
TRICKLING FILTER
130,800
3.44
BIO-CONTACTOR
2,094,100
55.1
BIO-CONT. BUILDING 14,300 S.F.
225,100
5.92
MIX. FLOC. CHEM. FEED
268,700
7.07
FILTER BACK PUMPS
556,400
14.64
2 CLARIFIER
254,200
6.69
AERATION CHLORINE
53,600
1.41
TER. TREAT. BUILDING 4,200 S.F.
147,500
3.88
FILTER BUILDING
94,000
2.47
AEROBIC DIGESTERS
348,300
9.17
VAC. FILTER PUMPS FEED
450,200
11.85
THICKENERS
177,200
4.66
ANAEROBIC DIGESTERS
14,100
.37
MECHANICAL PIPING
390,000
10.26
ELECT. DIST LIGHTING
30,000
.79
NEW PUMP STATION
194,300
5.11
EXIST. PUMP STATION
16,400
.43
EFF. PUMP STATION
162,000
4.26
NEW PUMP STA. BLDG 3,000 S.F.
40,700
1.07
OLD ADMIN. BUILDING
142,000
3.74
5,000 S.F. NEW ADMIN & VAC FILT. BLDG 6,100 S.F.
396,300
10.43

COST MODEL–TREATMENT PLANT COMPONENTS

FIGURE 19

DISCIPLINE		STRUCT. ENG.	ARCH., STRUCT.E.	CHEMIST., SAN.E.	ELEC. ENG.	MECH. ENG.	CIVIL ENG. LAND. ARCH	
TEAM NO		5.	4.	3.	2b.	2a.	1.	
WORKSHOP #1 TEAMS (CATEGORIES STUDIED) / TREATMENT PLANT COMPONENTS	TOTALS	UNDERGROUND STRUCTURES (Tanks, Excav.,Backfill Foundations)	BUILDINGS (Arch.,Struct.,Found.)	PROCESS (Equipment)	ELECTRICAL (Site, Process, Build.)	MECHANICAL (Site, Process, Build.)	SITE	WORKSHOP #1 Savings (100%)
SITE 784,700								16,600
. Grad., Rd., Park, Flood Protection	$ 378,000						$ 378,000	
. Landscape, Security, Walks	145,000						145,000	
. Drainage	33,700						33,700	
. Access Road	125,000						125,000	
. Influent Sewer	103,000						103,000	
PRIMARY-PRETREAT. 579,200								26,200
. Pretreatment	220,400	56,400		151,300	10,000	2,700		
. Pretreatment Bldg.	100,800		57,800		18,000	25,000		
. 2 Settling Tanks	232,600	183,500		46,600	2,500			
. Holding Tank	25,400	17,100		8,300				
SECONDARY 2,450,000								12,000
. Trick. Filter	130,800			123,300	7,500			
. Bio-Contactors	2,094,100	570,600		1,492,700	23,500	7,300		
. Bio-Cont. Build.	225,100		126,600		25,500	73,000		
TERTIARY-FINAL 1,374,600								00,900
. Mix, Chem. Feed, Floc	268,900	99,500		156,400	13,000			
. Filt., Back Pumps	556,400	147,300		362,600	46,500			
. 2 Clarifiers	254,200	182,400		67,300	4,500			
. Aeration, Chlorine	53,600			41,400	12,200			
. Tert. Treat Build.	147,500		80,200		28,500	38,800		
. Filter Build.	94,000		61,000		13,000	20,000		
SLUDGE 989,800								87,000
. Aerobic Digesters	348,300	171,200		133,600	4,500	39,000		
. Vac.Filt.,Pumps, Feed	450,200			427,900	22,300			
. Thickeners	177,200	90,800		82,900	3,500			
. Anaerobic Digesters	14,100				6,000	8,100		
INTERFACE 833,400								26,000
. Mech. Piping	390,000					390,000		
. Elect. Dist., Light	30,000				30,000			
. New Pump Station	194,300	92,500		72,500	27,500	1,800		
. Exist. Pump Station	16,400	11,400			5,000			
. Eff. Pump Station	162,000	89,500		72,500				
. New Pump Sta. Build	40,700		32,500		3,200	5,000		
OPERATIONAL SUPP. 538,300								70,200
. [illegible] Admin's. Build.	65,000				65,000			
New Adm.Vac.Fil.Build.	473,300		334,000		62,300	77,000		
BASE COST (PRE WORKSHOP)	$7,550,000	$1,712,200	$697,100	$3,239,300	$434,000	$687,700	$784,700	
[illegible] Workshop #1 Savings	1,438,900 *	362,000	322,300	209,000	73,400	155,600	316,600	.438
80% Savings For New Budget	1,151,120	289,600	257,840	167,200	58,720	124,480	253,280	900
New Budg. Design to Cost Model (Post Works	6,398,880	1,422,600	434,260	3,072,100	375,280	563,220	531,420	

*These and other potential savings to be refined by end of second workshop

COST MODEL MATRIX - TREATMENT PLANT COMPONENTS

WORKSHOP 1

Reproduced from best available copy.

FIGURE 20

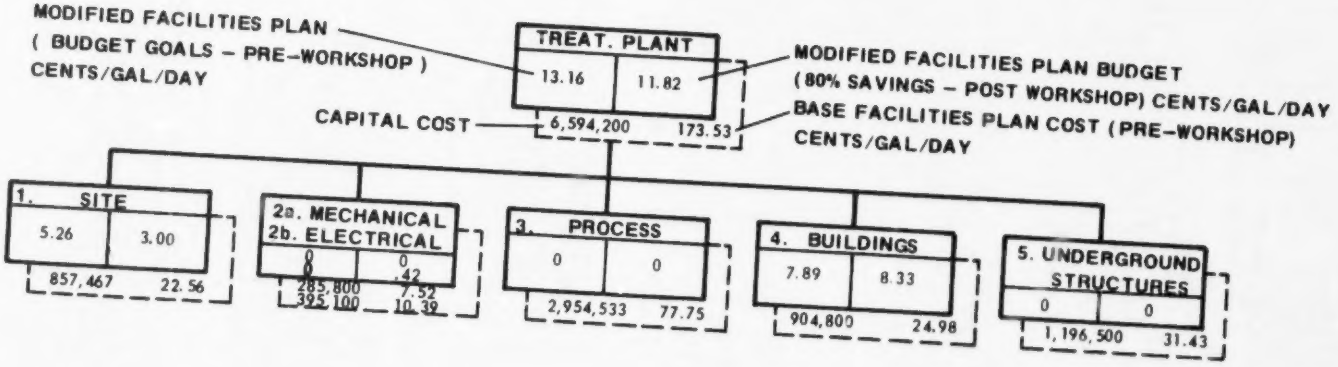

MODIFIED FACILITIES PLAN
(BUDGET GOALS – PRE-WORKSHOP)
CENTS/GAL/DAY
CAPITAL COST
MODIFIED FACILITIES PLAN BUDGET
(80% SAVINGS – POST WORKSHOP) CENTS/GAL/DAY
BASE FACILITIES PLAN COST (PRE-WORKSHOP)
CENTS/GAL/DAY
TREAT. PLANT
13.16
11.82
6,594,200
173.53
1. SITE
5.26
3.00
857,467
22.56
2a. MECHANICAL
2b. ELECTRICAL
0
0
0
.42
285,800
7.52
395,100
10.39
3. PROCESS
0
0
2,954,533
77.75
4. BUILDINGS
7.89
8.33
904,800
24.98
5. UNDERGROUND STRUCTURES
0
0
1,196,500
31.43

FIGURE 21.
COST MODEL – WORKSHOP NO. 2 TEAMS

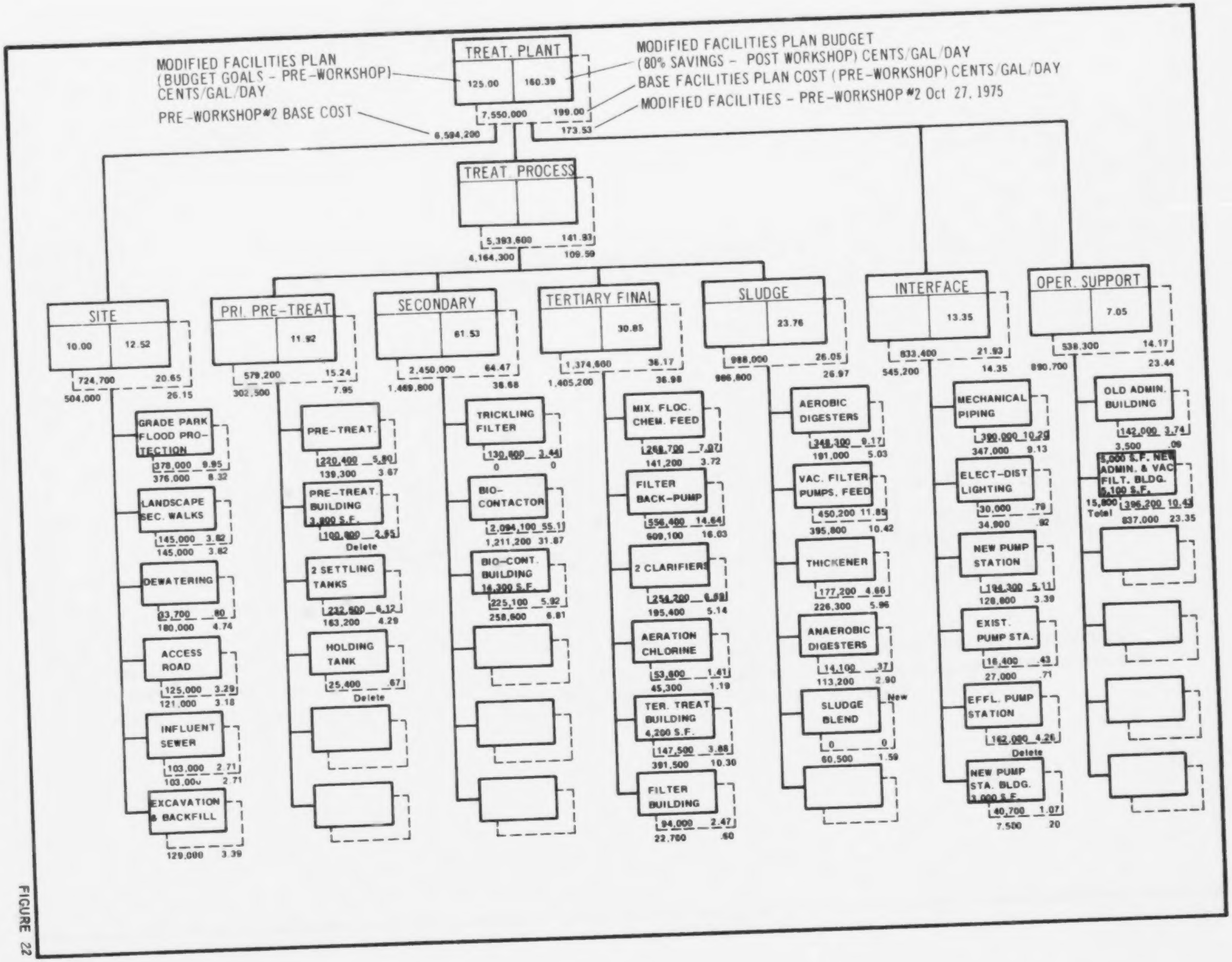

TREAT. PLANT
125.00
160.39
7,550,000
199.00
173.53
6,584,200
MODIFIED FACILITIES PLAN (BUDGET GOALS - PRE-WORKSHOP) CENTS/GAL/DAY
PRE-WORKSHOP#2 BASE COST
MODIFIED FACILITIES PLAN BUDGET (80% SAVINGS - POST WORKSHOP) CENTS/GAL/DAY
BASE FACILITIES PLAN COST (PRE-WORKSHOP) CENTS/GAL/DAY
MODIFIED FACILITIES - PRE-WORKSHOP #2 Oct 27, 1975
TREAT. PROCESS
5,393,600
141.93
4,164,300
109.59
SITE
10.00
12.52
724,700
20.65
504,000
26.15
GRADE PARK FLOOD PROTECTION
378,000
9.95
376,000
8.32
LANDSCAPE SEC. WALKS
145,000
3.82
145,000
3.82
DEWATERING
83,700
.80
180,000
4.74
ACCESS ROAD
125,000
3.29
121,000
3.18
INFLUENT SEWER
103,000
2.71
103,000
2.71
EXCAVATION & BACKFILL
129,000
3.39
PRI. PRE-TREAT
11.92
579,200
15.24
302,500
7.95
PRE-TREAT.
220,400
5.80
139,300
3.67
PRE-TREAT. BUILDING 3,800 S.F.
100,800
2.65
Delete
2 SETTLING TANKS
232,600
6.12
163,200
4.29
HOLDING TANK
25,400
.67
Delete
SECONDARY
61.53
2,450,000
64.47
1,469,800
38.68
TRICKLING FILTER
130,600
3.44
0
0
BIO-CONTACTOR
2,094,100
55.1
1,211,200
31.87
BIO-CONT. BUILDING 14,300 S.F.
225,100
5.92
258,600
6.81
TERTIARY FINAL
30.85
1,374,600
36.17
1,405,200
36.98
MIX. FLOC. CHEM. FEED
268,700
7.07
141,200
3.72
FILTER BACK-PUMP
556,400
14.64
609,100
16.03
2 CLARIFIERS
254,200
6.69
195,400
5.14
AERATION CHLORINE
53,600
1.41
45,300
1.19
TER. TREAT BUILDING 4,200 S.F.
147,500
3.88
391,500
10.30
FILTER BUILDING
94,000
2.47
22,700
.60
SLUDGE
23.76
988,000
26.05
986,800
26.97
AEROBIC DIGESTERS
348,300
9.17
191,000
5.03
VAC. FILTER PUMPS, FEED
450,200
11.85
395,800
10.42
THICKENER
177,200
4.66
226,300
5.96
ANAEROBIC DIGESTERS
14,100
.37
113,200
2.90
SLUDGE BLEND
New
0
0
60,500
1.59
INTERFACE
13.35
833,400
21.93
545,200
14.35
MECHANICAL PIPING
390,000
10.26
347,000
9.13
ELECT-DIST LIGHTING
30,000
.79
34,900
.92
NEW PUMP STATION
194,300
5.11
128,800
3.39
EXIST. PUMP STA.
16,400
.43
27,000
.71
EFFL. PUMP STATION
162,000
4.26
Delete
NEW PUMP STA. BLDG. 3,000 S.F.
40,700
1.07
7,500
.20
OPER. SUPPORT
7.05
538,300
14.17
890,700
23.44
OLD ADMIN. BUILDING
142,000
3.74
3,500
.09
5,000 S.F. NEW ADMIN. & VAC FILT. BLDG. 5,100 S.F.
15,800 Total
396,200
10.43
837,000
23.35

FIGURE 22

DISCIPLINE		STRUCT. ENG.	ARCH., STRUCT.E.	CHEMIST, SAN.E.	ELEC. ENG.	MECH. ENG.	CIVIL ENG. LAND. ARCH.
TEAM NO.		5.	4.	3.	2b.	2a.	1.
WORKSHOP #1 TEAMS (CATEGORIES STUDIED) / TREATMENT PLANT COMPONENTS	TOTALS	UNDERGROUND STRUCTURES (Tanks, Excav., Backfill Foundations)	BUILDINGS (Arch., Struct., Found.)	PROCESS (Equipment)	ELECTRICAL (Site, Process, Build.)	MECHANICAL (Site, Process, Build.)	SITE
SITE							
. Grad., Rd., Park, Flood Protection							316,000
. Landscape. Security, Walks							145,000
. Excavation, Backfill		129,000					
. Dewatering		180,000					
. Access Road							121,000
. Influent Sewer							103,000
PRIMARY-PRETREAT.							
. Pretreatment		26,000		83,900	22,300		
. Pretreatment Bldg.			7,100				
. 2 Settling Tanks		73,500	20,000	57,700	12,000		
. Holding Tank							
SECONDARY							
. Trick. Filter							
. Bio-Contactors		223,900		975,300	12,000		
. Bio-Cont. Build.			191,500		13,300	53,800	
TERTIARY-FINAL							
. Mix; Chem. Feed, Floc		31,800		98,100	11,300		
. Filt., Back Pumps		170,300		428,500	10,300		
. 2 Clarifiers		124,000		54,700	16,700		
. Aeration, Chlorine		35,000		9,500	800		
. Tert. Treat Build.			267,700		75,800	48,000	
. Filter Build.			22,700				
SLUDGE Sludge Blend		22,500		38,000			
. Aerobic Digesters		141,000		44,000	6,000		
. Vac.Filt., Pumps, Feed				383,800	12,000		
. Thickeners				219,600	6,700		
. Anaerobic Digesters			36,000	61,000	3,200	13,000	
INTERFACE							
. Mech. Piping				209,433			137,567
. Elect. Dist., Light							34,900
. New Pump Station		34,500		92,000	2,300		
. Exist. Pump Station		5,000	3,000	19,000			
. Eff. Pump Station							
. New Pump Sta. Build.			7,500				
OPERATIONAL SUPP.							
. Old Adminis. Build.			3,500				
. New Adm.Vac.Fil.Build.			345,800	180,000	190,400	171,000	
BASE COST (PRE WORKSHOP)	6,594,200	1,196,500	904,800	2,954,533	395,100	285,800	857,467
100% Workshop #2 Savings	561,340		395,785		20,000		145,555
80% Savings for New Budget	449,072		316,628		16,000		116,444
New Budg. Design to Cost Model (Post Works.)	5,145,128	1,196,500	588,172	2,954,533	379,100	285,800	741,023

NOTE: Workshop #2 - Teams will analyze:

Team #1 - Site - Column 1
Team #2 - Building/ Mechanical/Electrical - Columns 2a & 2b & 4
Team #3 - Maintenance, Operation & Replacement Costs

COST MODEL MATRIX - TREATMENT PLANT COMPONENTS

FIGURE 23

JUDICIAL PHASE

STUDY NO.

IDEA COMPARISON

Select the most feasible ideas or combination of ideas. List them below. List both the advantages and disadvantages of each idea to determine where additional work must be done.

IDEA	ADVANTAGE	DISADVANTAGE	RANK
Change dike slope	eliminates riprap	requires more fill and space.	2
Raise sides of tankage & equipment	saves fill - flood protection	more renovation costs	3
Allow site to flood	less expensive	conflicts with design criteria	1
		requires equipment removal	
		backup flooding	
Use alternate approach road	cost savings above flood level	citizen complaint link costs	6
Consolidate all but existing facilities on SE side of site	cost savings more efficient operation, maint.	heavier foundation multi level operation	1
All interface above ground	cost savings	maintenance	10
Supplement effluent sewer lines	cost savings	increase maint.	9
Postpone new line	cost savings	higher cost later (inflation)	8
Ground lower replace grass	life cycle savings	greater initial cost	7
Raise site	flood protection better structure	high initial cost	4
Flood protection Cronk Road build berm on pipes	cost savings	no access to site during floods	5
Minimum flood lights	cost savings	high initial costs	12
Rent site lighting from CLP	no initial cost no maintenance	long term costs	11
Structures foundation walls as dikes	reduces cost	increases interface	2
(Rated from 1-12)			
12 Best			

FIGURE 24

FLOOD PROTECTION

	CRITERIA	WEIGHT	RAW SCORE
A	Cost	6	4
B	Aesthetics	1	–
C	Safety	9	6
D	Continuation of of operation	10	7
E	O & M	9	6
F			
G			
H			
I			

CRITERIA SCORING MATRIX

	B	C	D	E	F	G	H	I
A	A3	A/C	D2	E3				
B		C3	D3	E3				
C			C/D	C1				
D				D1				
E								
F								
G								
H								

HOW IMPORTANT

1 – MINOR DIFFERENCE
2 – MEDIUM DIFFERENCE
3 – MAJOR DIFFERENCE

FIGURE 25
CRITERIA WEIGHTING PROCESS

JUDICIAL PHASE

ANALYSIS MATRIX

BASIC FUNCTION ▷ SITE FLOOD PROTECTION

List the best ideas from ranking and comparison techniques. Determine which one stacks up best against the desired criteria.

DESIRED CRITERIA	COST	O&M	SAFETY		AETHETICS	CONTINUITY OF OPERATION		
	a	b	c	d	e	f	g	TOTAL
WEIGHT OF IMPORTANCE (0-10)	6	9	9		1	10		
1. Dike PRESENT WAY	2 / 12	2 / 18	3 / 27		3 / 3	3 / 30		90
2. Consolidate & relocate (1) buildings	4 / 24	4 / 36	4 / 36		3 / 3	4 / 40		139
3. Buildings as dike (2)	3 / 18	3 / 27	3 / 27		2 / 2	4 / 40		114
4. Fill Entire site	1 / 6	2 / 18	4 / 36		3 / 3	4 / 40		103
5. Raise Facilities and equipment	2 / 12	1 / 9	1 / 9		2 / 2	2 / 20		52
6.								
7.								
8.								

EXCELLENT - 4 GOOD - 3 FAIR - 2 POOR - 1

FIGURE 26

to be $952,000, 13% of the preworkshop estimate or 17.8 times the eligible VE costs. The study also produced (MOR) maintenance, operation, and replacement savings estimated at $440,000 per year. The combined result of the two above savings was a savings in life cycle cost of about 35 percent.

The savings were based on a 30 year life and an interest rate of 10 percent. Annual costs were based on an estimated average cost over a 30 year life and assumed an inflation rate of 5.75 percent. It was also assumed that flow into the plant increased linearly from 1.8 mgd to 3.8 mgd over the 30 year life.

Tables 7 and 8 show the savings attributed to each team for the two workshops. Figure 27 summarizes the overall results for capital and life cycle costs. It is noteworthy that for both workshops only 80 percent of the apparent savings in initial cost were actually claimed. This was done in an attempt to reflect the fact that estimated costs tend to increase as detailed design progresses. It should also be noted that the savings in MOR costs shown in the table for Workshop I were based on a reportedly incorrect estimate of preworkshop costs and therefore, were not included in the overall savings.

The value engineering recommendations prepared by each team at the end of the workshops summarized the proposed design changes and expected savings resulting from the particular team's work. Because the studies were conducted by the design firm, the VE recommendations were actually reviewed by a team other than the original design team. Discussion of the significant aspects of each team's proposal is included below:

Workshop I - Site: The team proposed the consolidation of various new structures into one new structure as shown in Figure 28 and modifications of the perimeter flood control berm. This reduced the amounts of site grading and excavations as well as the fencing, piping, groundcover, drainage, rip rap and paving. The final layout proposed for the site was the work of all teams. Other items in the proposal included changing the grass covering most of the site to a natural ground cover having a higher initial cost but lower maintenance and life cycle costs and reducing the amount of site illumination from the pre-VE plan of lighting the entire site with pole mounted flood lights to using a minimum amount of building-mounted flood lights.

Workshop I - Energy: The major cost saving proposals by this group involved (1) the use of heat pumps for building heating and cooling employing plant effluent as a heat source and (2) the use of a programmed, electrical demand limiter to control the operating times of non-continuously running motors. This proposal also considered the energy savings to be gained from use of the alternate site plan proposed by other teams.

Workshop I - Process: This team developed new process flow sheet and hydraulic profile (Figure 29) on which the team could base many of their proposals. This new flow sheet retained the existing trickling

TABLE 7

COST SAVINGS SUMMARY - WORKSHOP I

TEAM	FIRST COST		ANNUAL MOR COST	
Site	$ 316,600		$ 38,400	
Energy-Mechanical (Site, Process, Building)	155,600		22,500	
Energy-Electrical (Site, Process, Building)	73,400		89,900	
Process (Equipment)	209,000		28,000	
Buildings (Arch., Struct., Found.)	322,300		33,800	
Underground Structures (Tanks, Exc., Backfill, Found.)	362,000		--	
TOTALS	$1,438,900	(100%)	$ 212,600	(100%)
Base Cost Pre-Workshop I	$7,550,000		$ 533,000	
Workshop I Savings	1,438,900	(100%)	212,600	(100%)
Savings (New Budget)	1,151,120	(80%)	--	
New Budget Design to Cost Model	$6,398,880		$ 320,400	

TABLE 8

COST SAVINGS SUMMARY - WORKSHOP II

TEAM	FIRST COST	ANNUAL MOR COST
Site	$ 145,555	--
Building	415,785	--
MOR	--	$ 440,000
TOTALS	$ 561,340	$ 440,000
Base Cost Pre-Workshop II	$6,594,200	$1,260,000
Workshop Savings	$ 561,340 (100%)	$ 440,000 (100%)
Savings (New Budget)	$ 449,072 (80%)	--
New Budget Design-to-Cost Model	$6,145,128	$ 820,000

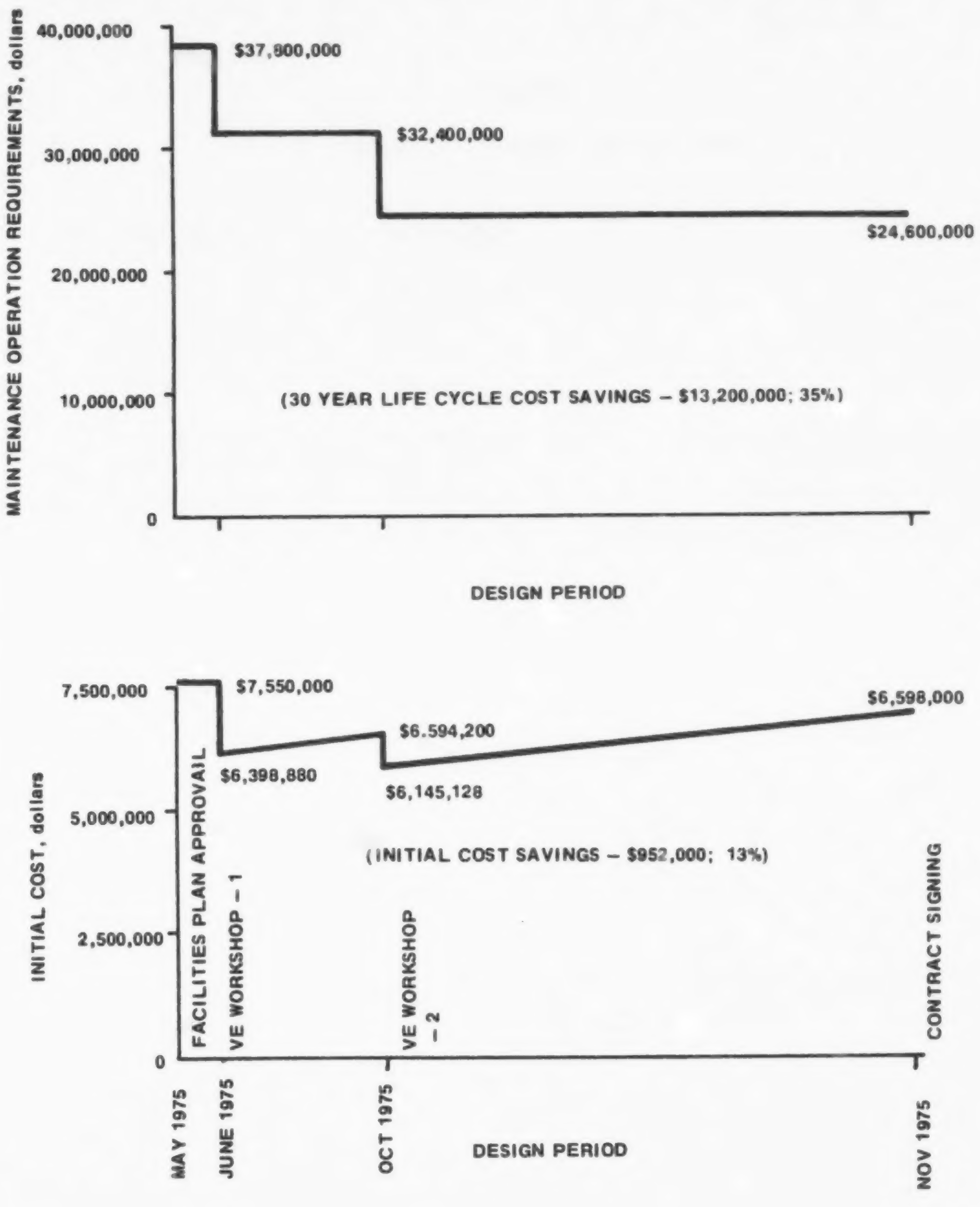
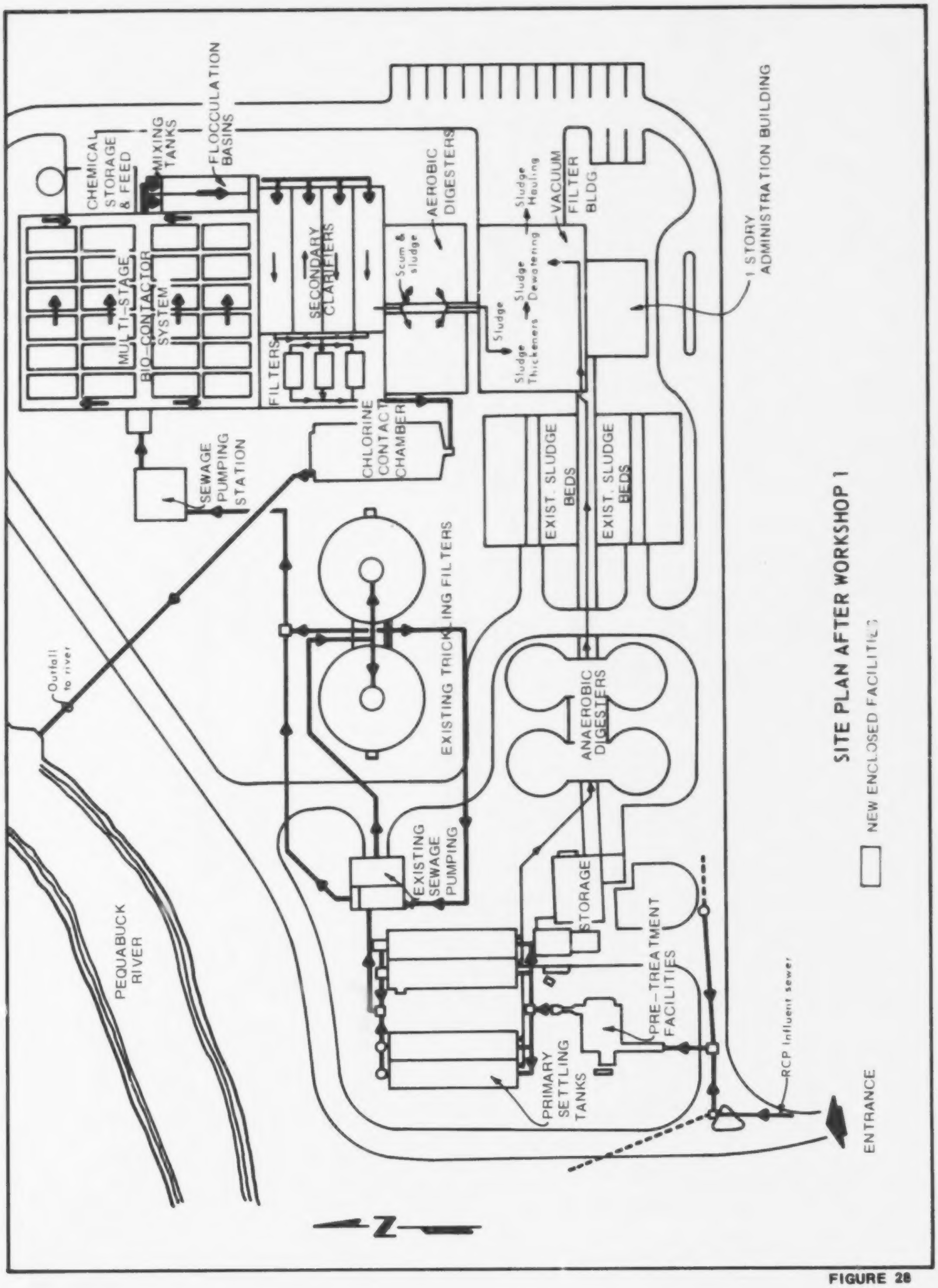


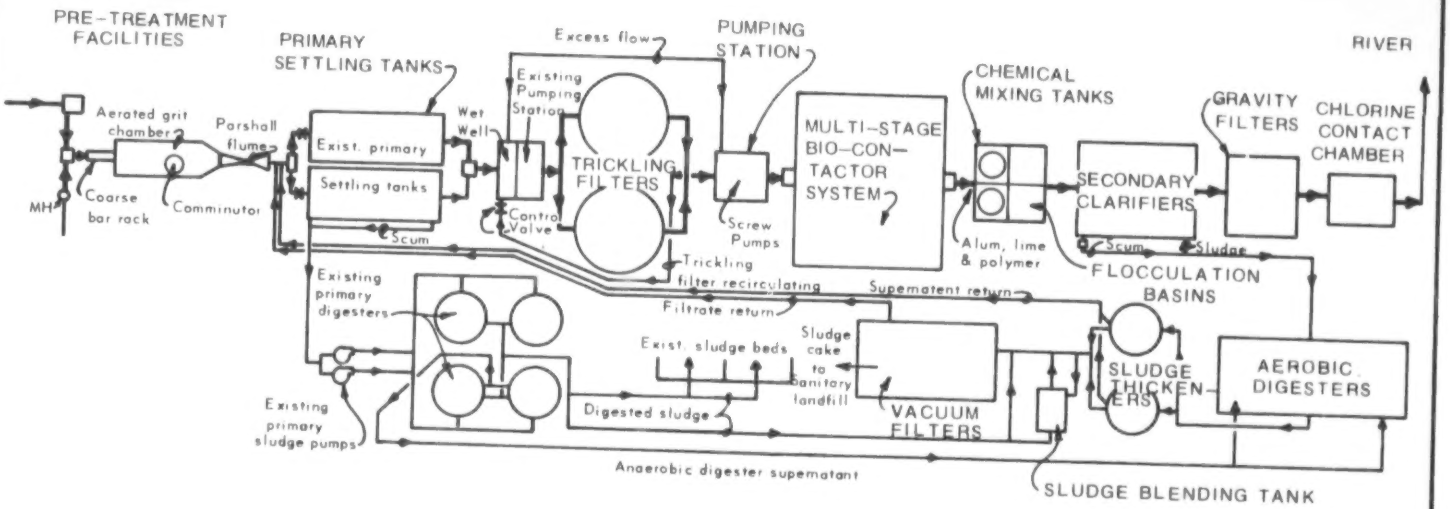
FIGURE 27. COST SAVINGS.



SITE PLAN AFTER WORKSHOP 1

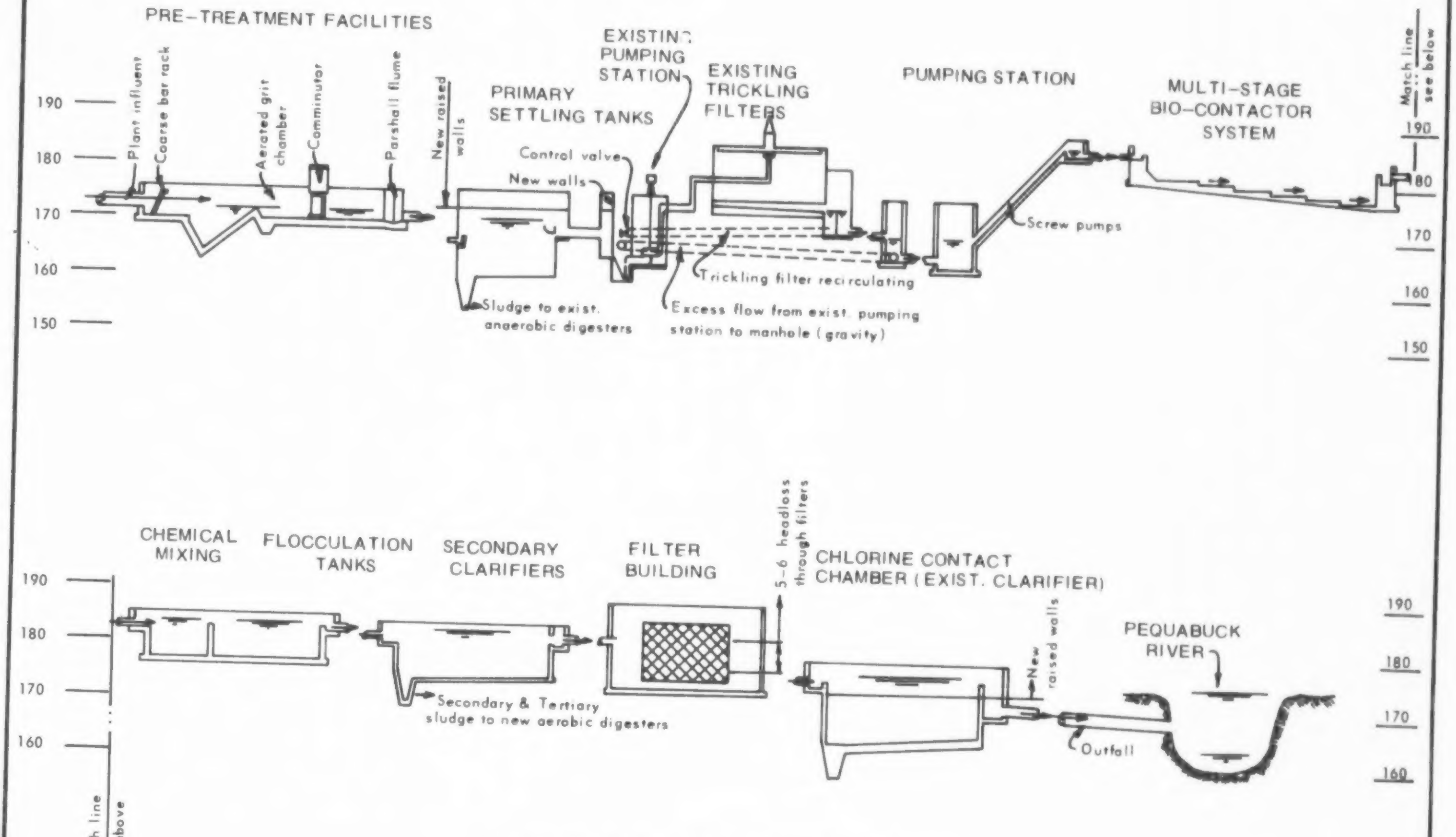
NEW ENCLOSED FACILITIES
CHEMICAL STORAGE & FEED
MIXING TANKS
FLOCCULATION BASINS
MULTI-STAGE BIO-CONTACTOR SYSTEM
SECONDARY CLARIFIERS
FILTERS
AEROBIC DIGESTERS
Scum & sludge
Sludge Thickeners
Sludge
Sludge Dewatering
Sludge Hauling
VACUUM FILTER BLDG
1 STORY ADMINISTRATION BUILDING
SEWAGE PUMPING STATION
CHLORINE CONTACT CHAMBER
EXIST. SLUDGE BEDS
EXIST. SLUDGE BEDS
EXISTING TRICKLING FILTERS
Outfall to river
ANAEROBIC DIGESTERS
EXISTING SEWAGE PUMPING
STORAGE
PRE-TREATMENT FACILITIES
PRIMARY SETTLING TANKS
PEQUABUCK RIVER
RCP Influent sewer
ENTRANCE
N

FIGURE 28


PRE-TREATMENT FACILITIES
Aerated grit chamber
Parshall flume
Coarse bar rack
Comminutor
MH
PRIMARY SETTLING TANKS
Exist. primary
Settling tanks
Scum
Wet Well
Existing Pumping Station
Control Valve
Excess flow
TRICKLING FILTERS
Trickling filter recirculating
PUMPING STATION
Screw Pumps
MULTI-STAGE BIO-CON-TACTOR SYSTEM
CHEMICAL MIXING TANKS
Alum, lime & polymer
FLOCCULATION BASINS
SECONDARY CLARIFIERS
Scum
Sludge
GRAVITY FILTERS
CHLORINE CONTACT CHAMBER
RIVER
Existing primary digesters
Existing primary sludge pumps
Filtrate return
Supematent return
Exist. sludge beds
Digested sludge
Sludge cake to sanitary landfill
VACUUM FILTERS
SLUDGE THICKEN-ERS
AEROBIC DIGESTERS
SLUDGE BLENDING TANK
Anaerobic digester supematant

SCHEMATIC FLOW DIAGRAM AFTER WORKSHOP 1

FIGURE 29A


PRE-TREATMENT FACILITIES
Plant influent
Coarse bar rack
Aerated grit chamber
Comminutor
Parshall flume
New raised walls
PRIMARY SETTLING TANKS
Control valve
New walls
Sludge to exist. anaerobic digesters
EXISTING PUMPING STATION
EXISTING TRICKLING FILTERS
Trickling filter recirculating
Excess flow from exist. pumping station to manhole (gravity)
PUMPING STATION
Screw pumps
MULTI-STAGE BIO-CONTACTOR SYSTEM
Match line see below
190
180
170
160
150
Match line See above
CHEMICAL MIXING
FLOCCULATION TANKS
SECONDARY CLARIFIERS
Secondary & Tertiary sludge to new aerobic digesters
FILTER BUILDING
5-6 headloss through filters
CHLORINE CONTACT CHAMBER (EXIST. CLARIFIER)
New raised walls
Outfall
PEQUABUCK RIVER

HYDRAULIC PROFILE AFTER WORKSHOP 1

FIGURE 29B

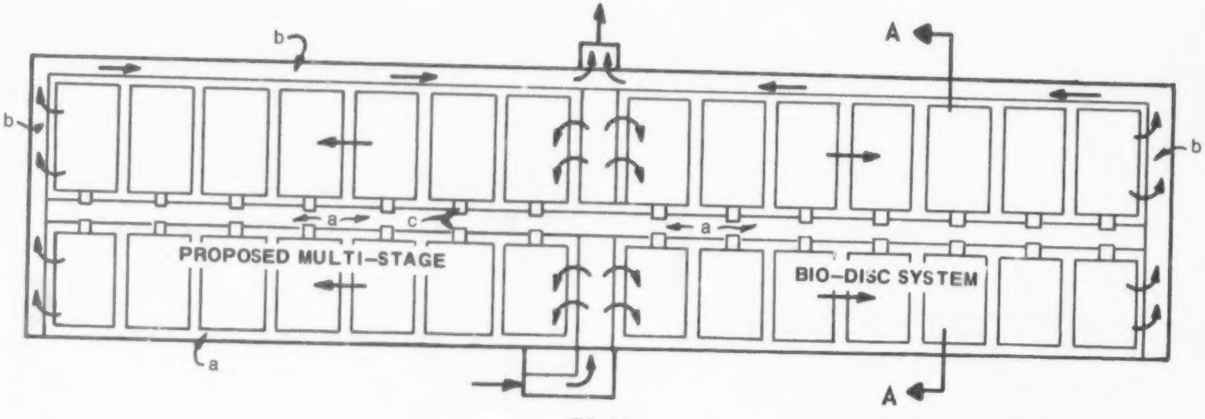
filters as roughing filters rather than converting them to equalization basins. The use of roughing filters reduced the organic loading on the biodisc process and allowed the deletion of four of the 28 biodiscs. Other proposals by the team included (1) changing a new low lift pump from the multi-speed centrifugal type to screw type (2) changing flocculation equipment from biodiscs to conventional flocculators (3) using gravity filters in place of pressure filters and thereby eliminate three pumps and a standby generator (4) converting existing (hydraulically inadequate) secondary clarifier to a chlorine contact basin and (5) eliminate the septic waste holding tank.

Workshop I - Buildings: Using the new flow scheme developed by the process team and the modified grading plan suggested by the site team, this team proposed reductions in building areas from an original layout of 40,200 SF to a new layout of 17,800 SF. The reductions were accomplished by eliminating the pretreatment building and using outdoor equipment rather than constructing a new enclosed pump station, using plastic covers over the biodisc structure in place of a concrete housing, consolidating the tertiary equipment building with the biodisc structure, and changing building systems for the administration/vacuum filter building to a pre-engineered system. The size of this last building was also reduced.

Workshop I - Underground Structures: Proposals by this team resulted mainly from consolidation of structures under the new site layout. This consolidation reduced the lengths of walls to be constructed and the amount of excavation. The configuration of the biodisc structure was changed from that shown in Figure 30 to that shown in Figure 31. This resulted in a reduction in lengths of walls, channels and walkways. Changes in design philosophy allowed the use of thinner concrete walls and the use of higher strength reinforcing steel allowed savings in steel weight. The substitution of wood for concrete construction of baffles walls in the chlorine contact tank and biodisc structure also produced some savings.

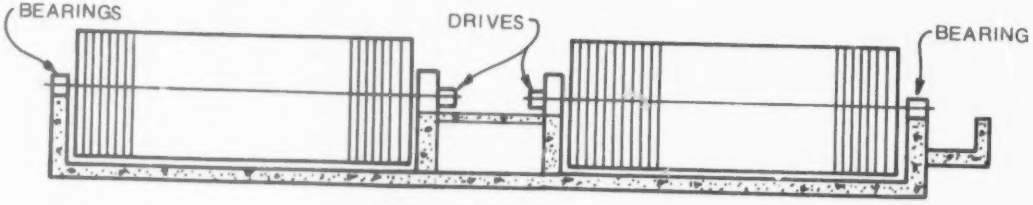
Workshop II - Site: Several items proposed by this team are shown in Figure 32. These include elimination of some access roads, changing material of a 24 inch pipeline from ductile iron to reinforced concrete, revision of the electrical distribution system to provide separate services to the new treatment building and to the existing control building. Other proposals involved changes to and reductions in landscaping, retention of an existing garage scheduled for demolition (the garage will be used by the Town for purposes not associated with sewage treatment).

Workshop II - Buildings: In the interim between workshops, it appears that the concrete structure over the biodiscs (replaced with plastic covers during the first workshop) was reincorporated into the design as was concrete framing for the administration building. A proposal of the second workshop replaced the concrete framing with steel framing and reduced the heights of both structures. Another proposal


A
A
b
b
b
a
a
a
c
PROPOSED MULTI-STAGE
BIO-DISC SYSTEM

PLAN
29 UNITS

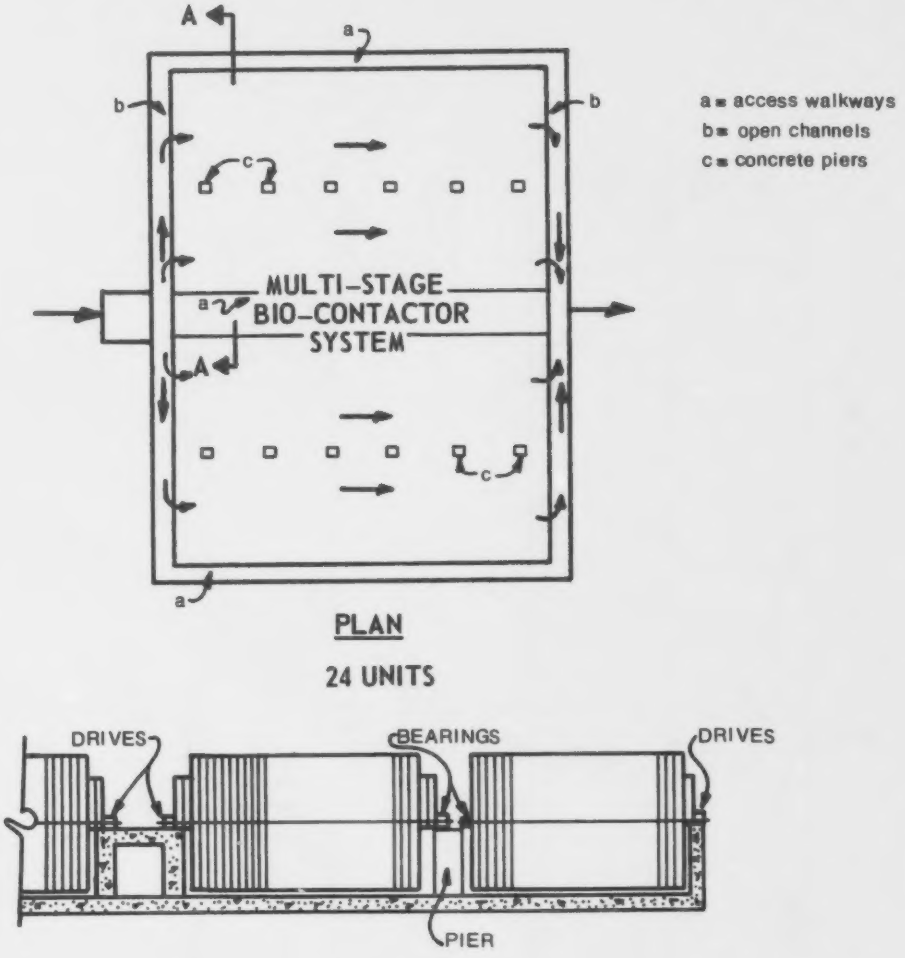
a = access walkways
b = open channels
c = drives


BEARINGS
DRIVES
BEARING

SECTION A–A

	28 BIODISCS (AS SHOWN)	24 BIODISCS (VE PROPOSAL)
TOTAL LENGTH OF WALLS	1160 lf	1040 lf
TOTAL LENGTH OF CHANNELS	410 lf	380 lf
TOTAL LENGTH OF ACCESS WALKS	200 lf	170 lf

FIGURE 30
BIODISC WALLS


A
a
b
b
a= access walkways
b= open channels
c= concrete piers
c
MULTI-STAGE
BIO-CONTACTOR
SYSTEM
a
A
c
a
DRIVES
BEARINGS
DRIVES
PIER

PLAN

24 UNITS

SECTION A-A

		SAVINGS OVER ORIGINAL WAY
TOTAL LENGTH OF WALLS	600 lf	440 lf
TOTAL LENGTH OF CHANNELS	400 lf	140 lf
TOTAL LENGTH OF ACCESS WALKS	200 lf	30 lf

ESTIMATED SAVINGS DUE TO NEW DISC LAYOUT: $75,000

FIGURE 31
BIODISC WALLS

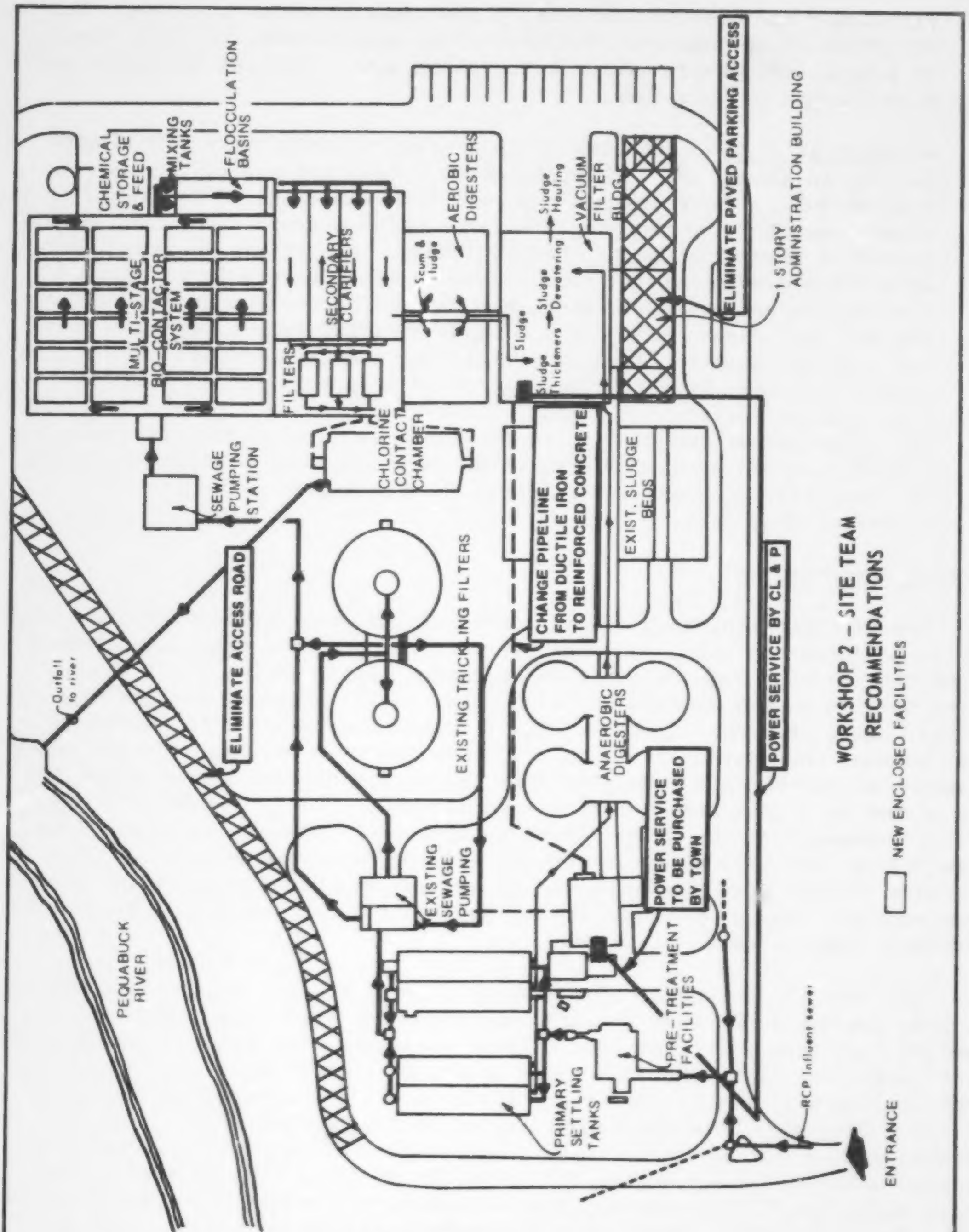

WORKSHOP 2 – SITE TEAM RECOMMENDATIONS
NEW ENCLOSED FACILITIES
PEQUABUCK RIVER
Outfall to river
ELIMINATE ACCESS ROAD
SEWAGE PUMPING STATION
CHEMICAL STORAGE & FEED
MIXING TANKS
FLOCCULATION BASINS
MULTI-STAGE BIO-CONTACTOR SYSTEM
SECONDARY CLARIFIERS
FILTERS
CHLORINE CONTACT CHAMBER
AEROBIC DIGESTERS
Scum & Sludge
Sludge
Sludge Thickeners
Sludge Dewatering
Sludge Hauling
VACUUM FILTER BLDG.
ELIMINATE PAVED PARKING ACCESS
1 STORY ADMINISTRATION BUILDING
EXISTING TRICKLING FILTERS
CHANGE PIPELINE FROM DUCTILE IRON TO REINFORCED CONCRETE
EXIST. SLUDGE BEDS
ANAEROBIC DIGESTERS
POWER SERVICE BY CL & P
POWER SERVICE TO BE PURCHASED BY TOWN
EXISTING SEWAGE PUMPING
PRE-TREATMENT FACILITIES
PRIMARY SETTLING TANKS
RCP Influent sewer
ENTRANCE
N

FIGURE 32

eliminated the planned basement of the administration building. Construction of the basement carried a high cost because of the presence of a high groundwater table at the plant site. Railing materials were also changed by this team.

Workshop II - MOR: The work of this team indicates very significant savings in annual and life cycle costs - $440,000 and $13,200,000 respectively. The major savings came from the areas of labor and electrical energy. The required staff was reduced from 18 to 9 men mainly through a re-evaluation of staffing needs. Electrical energy costs were reduced by providing time clocks to regulate the operations of equipment where operation might not need to be continuous at full rating all day. Such equipment included clarifier drives, biodisc drives and digester mixers. Savings in fuel oil consumption were expected to result from more effective insulation of various plant components. This included covering the long, above-ground influent line; covering the screw pumps; reducing airchange criteria in biodisc structure, thus reducing heating requirements; using additional earth-fill insulation at several structures; and reducing the heating criteria for the secondary digesters.

General Observations

The designer indicated he was quite pleased with the study and was now a strong advocate of VE. He would not mind having his competitors conduct VE studies on his projects although he thinks using his own staff, even those working on the design, for a VE study early in Step 2 has benefits. He felt using personnel from the client, particularly plant operators is good because they bring in a practical view and go away with a better understanding of the project. He also felt the representative of the State DEP who served as a team member during each workshop brought a different and useful viewpoint to the study. He also felt that the regional EPA office should also have provided a representative but none were available. The designer thought that the number of teams used and the timing of the two workshops was nearly optimum. He also stated that two workshops are highly desirable even on small projects.

The VETC indicated that for reasons already given, it is acceptable to include designers on teams in early workshops but that it is better to exclude them from participation in later workshops. He recommended that the best talent available should be used on the VE teams. By using "experts", some savings will result from their review of a less experienced person's design. They will know the latest design techniques and, during the designers review and rebuttal, their suggestions will carry more weight. Because maintenance and operations costs are difficult to set over a long plant life, the VETC recommends that a sensitivity analysis be performed on the life cycle costs. When LCC's for various alternates having different first costs are close, redetermining LCC's over a range of inflation rates may help to select the probable best alternate.

The VETC felt that the imposition of constraints should be kept to a minimum. Since process selection possibly has the greatest influence on cost, its review offers a high potential for savings and shouldn't be excluded from the study.

The VETC felt that conducting the VE workshop within the 40 hour session is important. This gets the work done efficiently and without delays to the project. To conduct the study in 40 hours, however, all needed information must have been gathered by the VETC well before the workshop. To avoid the common problem of having time to estimate the costs of complex alternates during the study, these alternates can often be anticipated by the VETC and designer during the preworkshop period and critical cost information for the team gathered before the workshop.

The VETC expressed that in order to get qualified VE teams, it is necessary to have them selected and approved at the time of grant approval. He likened the selection process to that of selecting subcontractors in the construction industry. If a subcontractor or VE team is not selected and a price agreed upon at the time of grant approval, then there will be "shopping" later. The result will be a lower price and a less qualified team. To remedy the situation he suggests that the teams, including the qualifications of each team member and the VETC, the price and the workplan be approved and fixed at the time the Step 2 grant is approved.

The State indicated that they were happy to have participated in the study and, time permitting, would participate in future studies when asked.

The Town Manager, who was a team member, spoke highly of the study and of VE in general. He felt that VE was worth the cost and should be applied to all sewage treatment projects. Although he thought the study was conducted well and certainly saved money, he would recommend that future studies be made by an outside firm. He also felt that review of process should be encouraged during the early VE study but not during one made late in the design period.

On the subject of initial acceptance, he indicated that the Town Council was somewhat reluctant to accept the idea of a VE study. However, because the plant's cost had risen so much and because some of the council members had worked for a corporation where VE had been used, they were receptive to proceeding with the study.

CLEVELAND, OHIO SOUTHERLY PROJECT

This report is based on interviews held on December 7 and 8, 1976 in Cleveland and Twinsburg, Ohio with the VE firm, the Cleveland Regional Sewer District, the designer, and the State EPA.

Description of the Proposed Project Prior to the VE Study

The Southerly Wastewater Treatment Plant is one of three that are operated by the Cleveland Regional Sewage District. The plant was originally installed in 1927. The plant modifications discussed herein were proposed to meet new treatment criteria calling for a higher level of treatment and to increase the capacity from 115 mgd to 200 mgd (average flow). The Southerly plant also filters and incinerates 1.8 mgd of sludge from the Easterly plant.

The flow and effluent criteria to which the plant is to be upgraded are:

200 mgd - Design Flow
400 mgd - Peak Flow for Full Treatment
735 mgd - Storm Flow, Primary and Disinfection
7 ppm - Monthly Avg. BOD and SS
1 ppm - Monthly Avg. Phosphorus, Not Over
2 ppm - Monthly Avg. Ammonia Nitrogen, Not Over (Summer)
200/100 ml - Monthly Mean Coliform, Not Over

The proposed project prior to the VE may be described as follows (See Figure 33):

Headworks--

To be modified to allow combining of flow of three existing interceptors for routing to new screens and grit removal tanks. Provision for routing this flow to existing detritus tanks are to be made. The design is based on a flow of 735 mgd.

Screens--

Seven new 125 mgd mechanical screens are to be installed. Screenings are to be collected by conveyor and disposed by landfill.

Grit Removal--

Existing two detritors used only as described above. Seven new grit chambers to be installed.

Primary Settling Tanks--

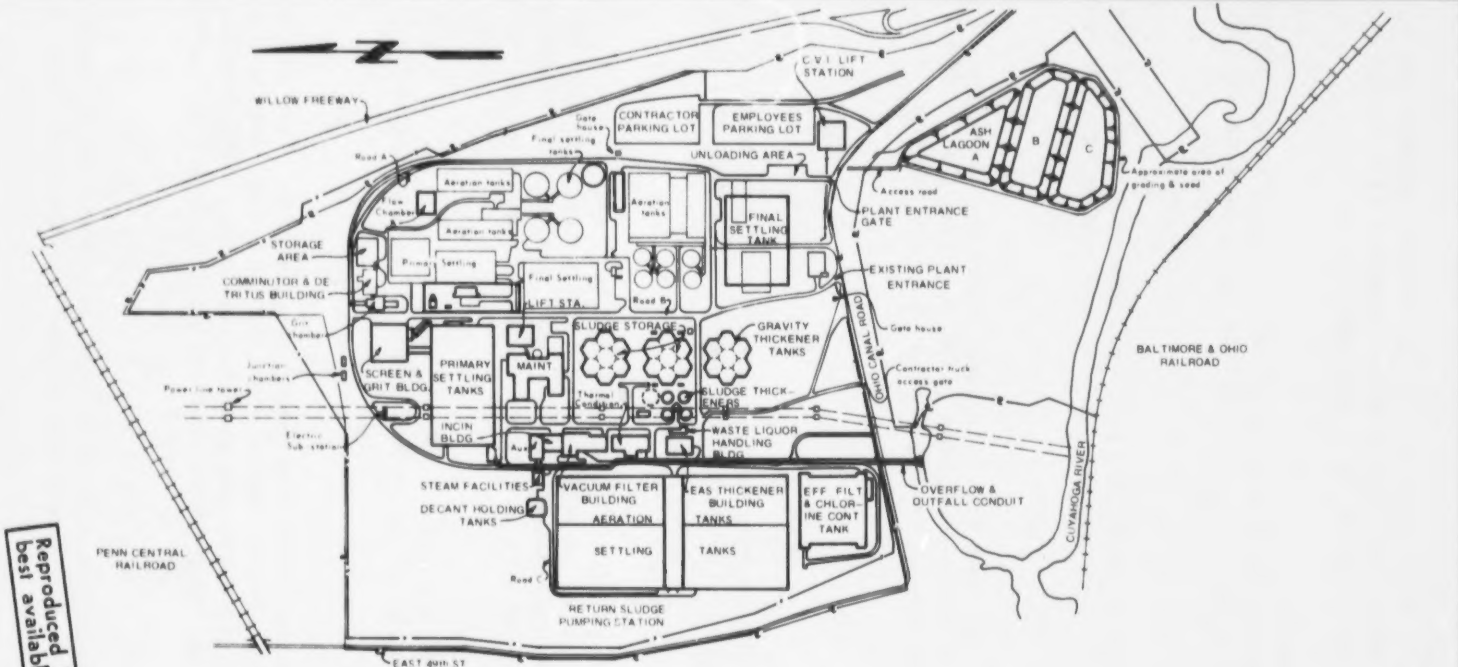
There were 10 existing basins with a total surface area of 77,400 SF. Eight new basins with a total surface area of 173,000 SF are to be added.

First Stage Aeration Basins--

Two-stage aeration and settling tanks are to be used for respective carbonaceous removal and nitrification. Existing aeration tanks are to be used in the first stage and new tanks are to be installed for the second stage. The existing aeration tanks provide a detention, disregarding recycled flow and drawoff of primary effluent dilution water, of about 2.5 hours. The total BOD load to the first stage tanks would be 93 lbs. per 1000 cu. ft. A BOD removal of 75% is projected.

First Stage Settling Basins--

Ten existing clarifiers offered 110,000 sq. ft. of surface area. New clarifiers would be added to increase total surface area to 302,500 sq. ft. to provide a surface settling rate of about 663 gallons per sq. ft. per day.


N
WILLOW FREEWAY
PENN CENTRAL RAILROAD
STORAGE AREA
COMMINUTOR & DE TRITUS BUILDING
Grit chamber
Junction chambers
Power line tower
Electric Sub station
Road A
Flow Chamber
Aeration tanks
Aeration tanks
Primary Settling
Final settling tanks
Gate house
CONTRACTOR PARKING LOT
EMPLOYEES PARKING LOT
UNLOADING AREA
C.V.I. LIFT STATION
Aeration tanks
FINAL SETTLING TANK
Final Settling
LIFT STA.
Road B
SCREEN & GRIT BLDG.
PRIMARY SETTLING TANKS
INCIN BLDG
MAINT
Thermal Condition
SLUDGE STORAGE
GRAVITY THICKENER TANKS
SLUDGE THICKENERS
WASTE LIQUOR HANDLING BLDG
Aux
STEAM FACILITIES
DECANT HOLDING TANKS
VACUUM FILTER BUILDING
AERATION
SETTLING
EAS THICKENER BUILDING
TANKS
TANKS
EFF FILT & CHLORINE CONT TANK
Road C
RETURN SLUDGE PUMPING STATION
EAST 49th ST
ASH LAGOON A
B
C
Access road
Approximate area of grading & seed
PLANT ENTRANCE GATE
EXISTING PLANT ENTRANCE
OHIO CANAL ROAD
Gate house
Contractor truck access gate
OVERFLOW & OUTFALL CONDUIT
CUYAHOGA RIVER
BALTIMORE & OHIO RAILROAD

SITE PLAN

Reproduced from best available copy.

FIGURE 33

Second Stage Aeration Basins--

Ten new basins with a total capacity of 39,300,000 gallons are provided for nitrification. The detention disregarding recycled flow is about 4.65 hours with an estimated BOD load of 12.3 lbs/1000 cf.

Second Stage Settling Basins--

Ten basins with a total surface area of 323,000 sq. ft. and SWD of 14' are proposed. At design flow rates, the surface settling rate will be about 550 gallons per sq. ft. per day.

Tertiary Filters--

Tertiary filters with an area of 52,000 sq. ft. were proposed based on 3.33 gpm per sq. ft. at average flow and 6.0 gpm per sq. ft. at peak flow.

Chlorination--

Two contact basins designed for 15 minute detention at a flow of 400 mgd are proposed. Chlorinators are sized to apply 10 mg/l at 400 mgd. The overflow from primary basins during storms is to be given a dosage of 15 mg/l.

Solids Handling

Degritters--

Primary sludge and any stored Easterly Plant sludge will be diluted by primary effluent and pumped through cyclone degritters. Ten 1000 gpm units are proposed.

Gravity Thickeners--

The above degritted sludges will be applied to gravity type thickeners. Six existing digesters are to be modified to gravity thickening tanks. Thickened sludge will be stored in modified existing anaerobic digesters. Thickener overflow (both primary and waste activated) is returned to the primary settling tanks.

Waste Activated Sludge Thickeners--

The Southerly Plant waste activated sludge will be thickened by centrifuges.

Thermal Conditioning--

A thermal conditioning (heat treatment) is proposed. Five 280 gpm units will be furnished. The thermally conditioned sludge will be thickened to about 8% in modified existing elutriation tanks. The thermally conditioned sludge can be filtered without thickening at reduced vacuum filtration rates.

Vacuum Filters--

Two additional filters are proposed. The existing facilities comprise ten 500 sq. ft. filter units. The design filter loading rate is 5 lbs per sq. ft. per hour.

Incinerators--

The four existing incinerators are to have major repairs and no additional units provided. They are 22'3" diameter, each having 9 hearths. Filtered sludge can be hauled if there is an incineration shutdown.

The VE Study

Background--

Contracting for design, equipment purchasing and construction of the Southerly improvements had been broken into eighteen packages, which subsequently were consolidated into sixteen. The purpose of the division was to keep the packages small enough to involve smaller firms in competition, and to avoid excessive markups on major equipment. The VE studies for Southerly were similarly divided. Construction on seven of the sixteen contract packages had been completed or was under way, and bids imminently due on two others, when it was determined that three designs, all 90% complete, would be subjected to value analysis. The packages to be value engineered were Primary Facilities, C-10, Second Stage Facilities, C-14, and Effluent Filter Building, C-15. At this writing (Dec. '76) the VE Team is under contract with the CRSD to VE Contract 16, and is doing the estimating and other preparatory work for the actual study.

Since the design was substantially complete and construction schedule pressing, there was no likelihood that a process change could be implemented or would be cost effective. The VE firm, selected by the staff of the Cleveland Regional Sewer District, was, therefore, one better versed in construction techniques than in treatment technology.

The Cleveland Regional Sewer District (CRSD) advertised for Construction Management (CM) support on the complete sixteen contract upgrading of the Southerly plant. A firm was selected, and a grant application was made for CM funding. CRSD desired the CM orientation to insure ease of construction of the proposed design and to validate cost estimates. It was suggested by Region V that these functions of CM could be obtained through a VE study. The CRSD and the VE firm then contracted directly for the VE Study, with no direct involvement of the design firm. Of the three contracts to be value engineered, two (contracts 10 and 14, first and second stage facilities, respectively) had been completed, including the Designer's review, at the time of this report. The Designer's review of the third (contract 15) had not yet been completed. Thus, this discussion will be limited to the two completed VE studies on Contracts 10 and 14.

Organization--

The VE teams were composed from structural, mechanical, and architectural personnel from the VE firm. Two CRSD, sanitary-civil engineers were members of teams in each study. There was no Designer representative present during the study.

The VE teams were completely sequestered from their normal work and the studies were each run in ten full days, consecutive except for a Sunday. The CRSD indicated to the VE teams that any questions that could not be answered from the drawing file, were to be addressed to the CRSD, who in turn would direct the inquiry to the Designer, and return with an answer.

The Designer expressed a wish that the VE Team might have been more process oriented, "so they wouldn't suggest so many obviously unfeasible ideas (smaller tunnels, combining flows in fewer, larger pipes, etc.)". The Designer did acknowledge, however, that for this study of a substantially complete design, it probably was best to have a construction-oriented team.

Considerable effort was put into having the preliminary VE report published concurrent with study completion. A presentation was made to the Owner, CRSD, U.S. EPA, Ohio EPA, and the design firm.

The Designer's project manager was the first to review the VE study recommendations for the Designer. Sepcific points were then referred to department managers and lead designers, in such disciplines as structures, electrical, architecture, soils, etc. Comments were also presented to CRSD who referred them to the VE firm to make sure that recommendations were properly interpreted.

Level of VE Effort

Two five-man teams conducted the study on Contract 10 and three five-man teams on Contract 14. Each study was ten full days in duration.

For Contracts 10 and 14, the fee for the VE Team's activities was $225,000. The Designer's costs for supporting and reviewing the study were $13,800.

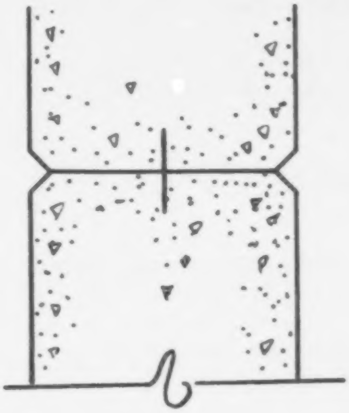
VE Recommendations

The following summarize the accepted and rejected VE recommendations for the two VE studies:

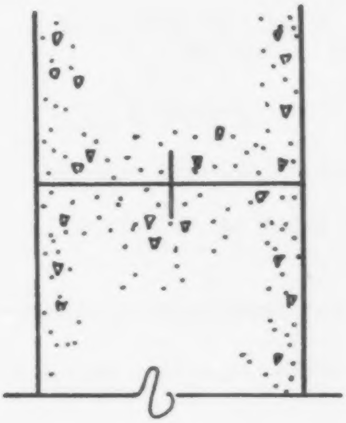
CONTRACT 10 - PRIMARY FACILITIES, CLEVELAND-SOUTHERLY

Accepted Suggestions	Savings
1. Decrease Scope of Demolition Work	$269,374
2. Reduce Size of Tunnels, Reduce Scope of Access Building, and Eliminate Segments at Tunnel (Recom. by VE = $508,405)	$165,375
3. Delay Access to One Side of Maintenance Building	$179,629
4. Use On-Site Material to Backfill Above Pipeline	$ 86,340

Accepted Suggestions	Savings
5. Eliminate Chamfer at Construction Joints. Leave Edges Square (See Figure 34)	$ 19,440
6. Use Aluminum Extrusion In Lieu of Built Up Sheet Parts for Stop Plank (See Figure 35)	$ 36,356
7. Use NEMA 1 Enclosures in Lieu of #12 for MCCs	$ 29,499
8. Reduce Backfill Compaction Requirements (Recom. by VE = $765,760)	$172,755
9. Reduce Scope of Broadway South Interceptor Flume	$244,859
10. Eliminate Duplicate Meter on Easterly Sludge Line	$ 35,267
11. Increase Spacing of Construction Joints	$ 66,399
12. Eliminate 1" of Non-Shrink Grout in Primary Tank	$574,260
13. Simplify Detail of Rail at Bottom of Primary Tank (See Figure 36)	$ 23,721
14. Eliminate Roof on Grit Building	$200,167
15. Defer Construction of the Bar Screen	$112,988
16. Eliminate Roller Gates to #2 Primary Influent Channel	$133,482
17. Eliminate Crane for Screenings Containers	$ 40,990
18. Simplify Design of Bar Screens (recommended savings $35,565)	$ 14,000
19. Use Aluminum in Lieu of Stainless Steel for Doors and Door Frames (recommended savings $24,684)	$ 12,600
20. Redesign Bottom Rail in Grit Channel	$ 8,400
21. Eliminate Future Grit Chute	$ 3,049
22. Delete Requirement for Test witness for Blower ASME Test	$ 2,300

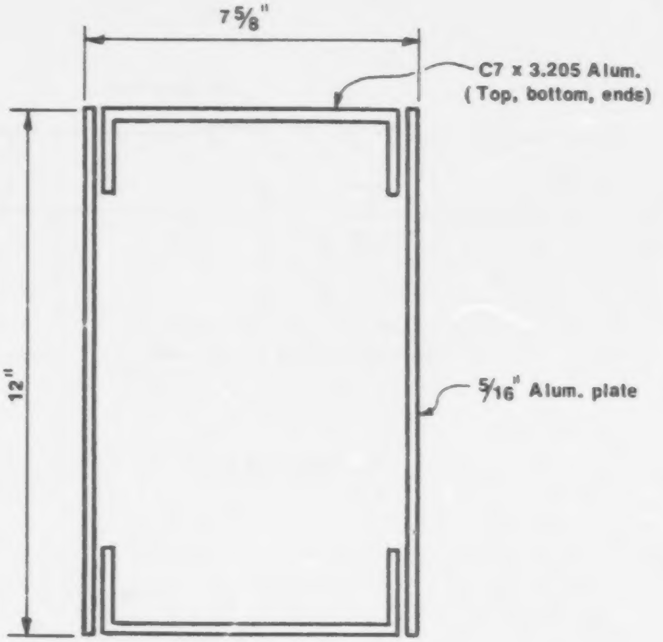


PRESENT TYPICAL JOINT DETAIL

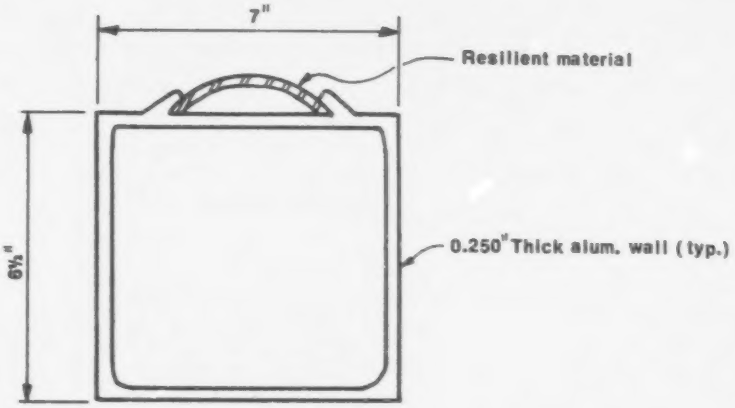


REVISED TYPICAL JOINT DETAIL

FIGURE 34
CONTRACT 10, ITEM 5

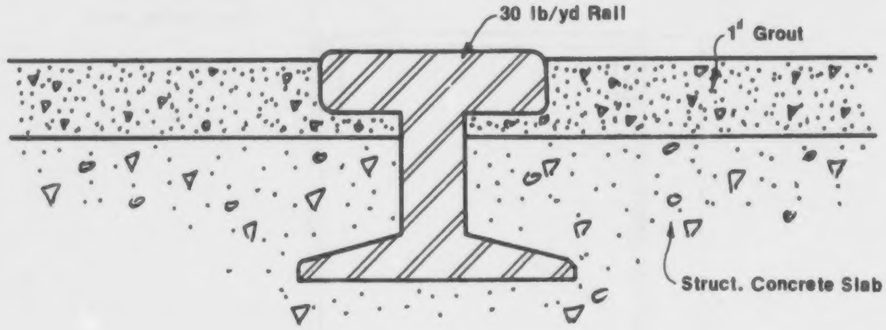

7 5/8"
C7 x 3.205 Alum.
(Top, bottom, ends)
12"
5/16" Alum. plate

ALUMINUM STOP PLANK – TYPICAL SECTION

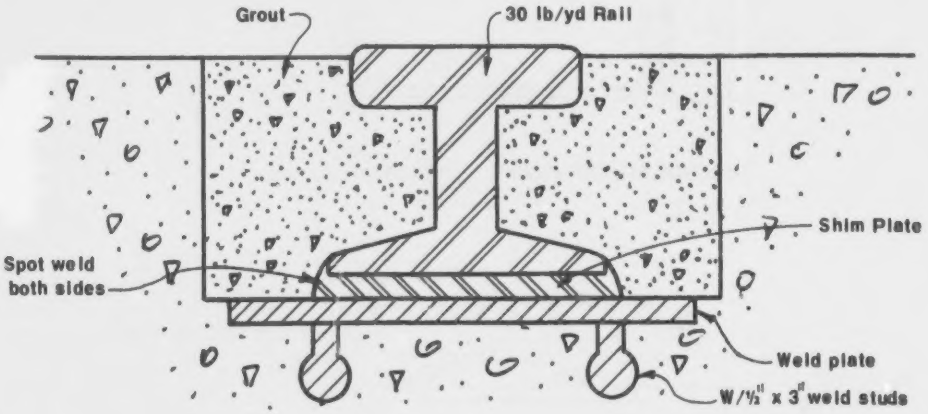

7"
Resilient material
6½"
0.250" Thick alum. wall (typ.)

ALUMINUM STOP PLANK – PROPOSED EXTRUSION

FIGURE 35
CONTRACT 10, ITEM 6


30 lb/yd Rail
1" Grout
Struct. Concrete Slab

REVISED DETAIL


Grout
30 lb/yd Rail
Shim Plate
Spot weld both sides
Weld plate
W/½" x 3" weld studs

PRESENT DETAIL

FIGURE 36
CONTRACT 10, ITEM 13

Total Accepted Savings,
Contract 10, Primary Facilities $2,431,250

Rejected Suggestions (S) and Justification (J)

1.	(S) Reduce cement content of concrete	$ 69,900
	(J) Contrary to ACI-350. Low reliability.	
2.	(S) Use #57 stone in lieu of #8 stone in underdrainage system	$ 28,901
	(J) Soils consultant advises the #57 stone will not function as reliably.	
3.	(S) Change design of curbing	$ 27,524
	(J) Does not allow for installation of wearing course after construction. Would require curbing twice.	
4.	(S) Use thinner stainless steel handrails	$ 56,704
	(J) Walls only 1/16" thick are too difficult to weld.	
5.	(S) Raise invert of underdrain in Primary Tanks	$ 18,783
	(J) Would require more Ells and Tees, hence more costly.	
6.	(S) Eliminate mud mat under Primary Tanks	$ 39,810
	(J) Would cause underdrain contamination; would reduce underdrain course thickness; would cause variations in depth of concrete over reinforcing steel.	
7.	(S) Use metal deck forms for tunnel roofs	$ 16,044
	(J) Would not provide necessary pipe supports; would require painting maintenance.	
8.	(S) Use earth fill in lieu of washed mortar sand for fill	$583,142
	(J) "Type C Fill" was interpreted to mean washed sand. In the Cleveland area, this is not a proper interpretation.	

9.	(S) Eliminate divider wall in Primary Influent Channel #2 (J) Divider enables one channel to be taken out of service for maintenance without flow interruption.	$ 61,325
10.	(S) Use masonry unit walls in lieu of precast panels and glass panels (J) Does not equal "U" Value or aesthetic appeal of precast panel. Will require lighting power to replace daylight.	$190,846
11.	(S) Use precast roof panels. Eliminate parapet and coping. Use rigid insulation. (J) Number of penetrations in roof slab mitigates against precast. Cannot get 20 year bond on gravel stop roof. Rigid insulation requires extensive drawing changes to get necessary additional pitch.	$ 35,913
12.	(S) Reduce height of pipe gallery (J) Height of present design allows future installation of grit ejector equipment.	$ 29,885
13.	(S) Delete roof hatches in grit building (J) Hatches are required to permit removal of bar screens.	$ 10,029
14.	(S) Relocate aeration compressor from grit building to screen building (J) No available area in screen building. Present design locates all compressors together.	$ 7,787
15.	(S) Replace concrete stairs with steel (J) Steel would require more maintenance.	$ 3,542
16.	(S) Eliminate power operator for overhead door (J) Would probably result in fewer than ideal manual operations, hence loss of heat and release of odor.	$ 2,091

17.	(S) Eliminate elevator in sludge degritting building (J) Cleveland Reg. Sewer Dist. prefers to retain elevator.	$ 88,901
18.	(S) Reduce basement height in sludge degritting building from 20' to 16' (J) Height required for installing equipment	$ 29,090
19.	(S) Replace aluminum gratings and platforms in screen and degritting buildings with galvanized steel. (J) Galvanized steel would require increased maintenance.	$ 8,344

Contract #10, Primary Facilities

Totally Rejected Suggestions	$1,312,474
Total, Partially Rejected Suggestions	979,686
Approved Suggestions	2,431,250
Proposed by VETC	4,723,408

CONTRACT 14 - SECOND STAGE FACILITIES - CLEVELAND SOUTHERLY

	Accepted Suggestions	Savings
1.	Replace steel sludge activated sludge return line with cast-in-place concrete. (Recommended savings was $441,231. Designer rejected cast-in-place because of pipe fitting requirements and losses, but cut steel pipe wall thickness for savings shown).	$192,403
2.	Incorporate slope in bottom of settling tanks instead of top. (See Figure 37).	$322,317
3.	Use single wall tank dividers in lieu of double wall with joint filler. (Recommended savings was $569,559. Designer accepted single wall between settling tanks, but not aeration tanks, because of cantilever walls were not cost effective.	$192,226
4.	Replace 12" diameter aluminum baffle wall pipe sleeves with steel sleeves.	$ 26,626
5.	Relocate stairs to astride the North-South tunnel.	$ 21,164

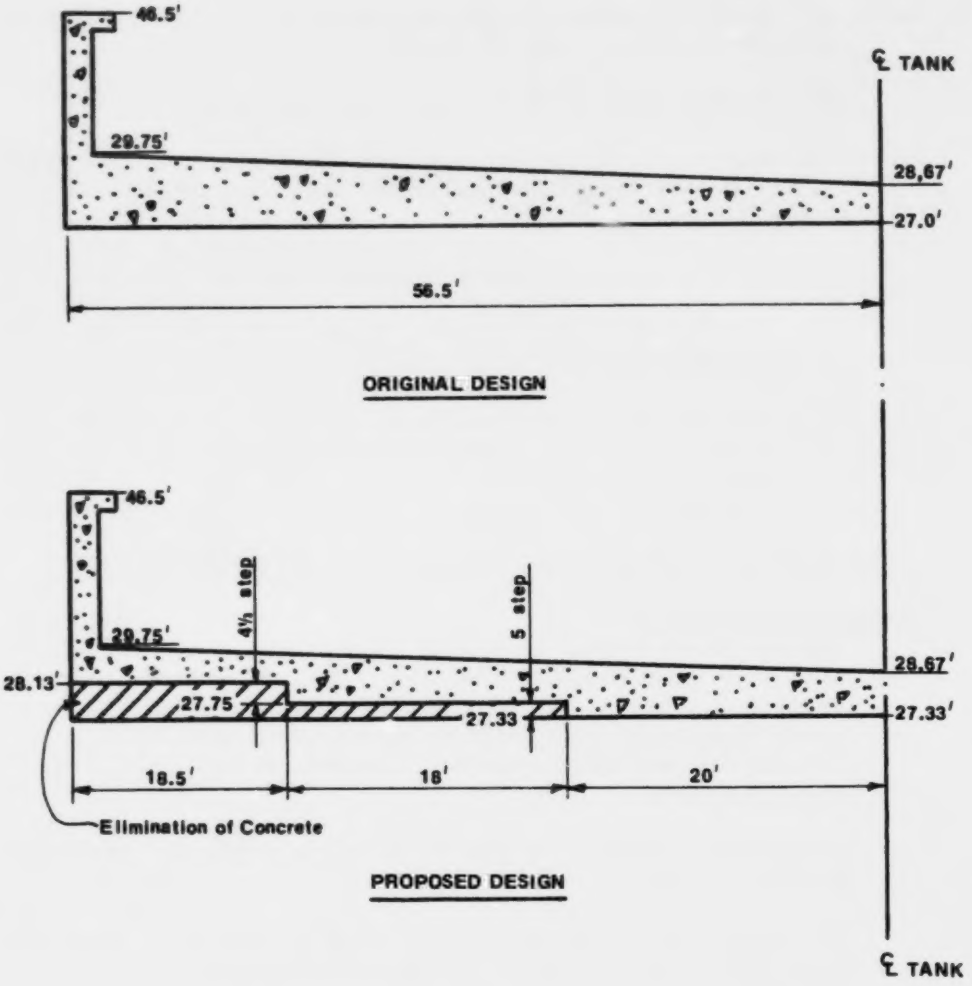
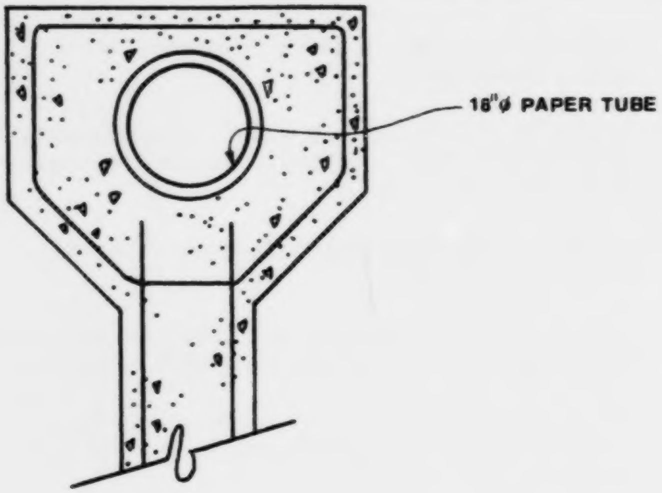

46.5'
29.75'
28,67'
27.0'
56.5'
ORIGINAL DESIGN
46.5'
29.75'
4½ step
5 step
28.67'
28.13'
27.75'
27.33
27.33'
18.5'
18'
20'
Elimination of Concrete
PROPOSED DESIGN
℄ TANK
℄ TANK

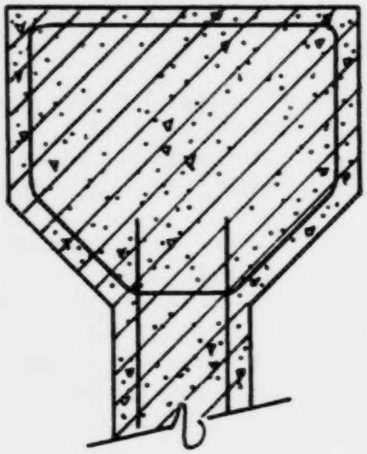
FIGURE 37
CONTRACT 14, ITEM 2

6.	Delete tank beam adjacent to air header.	$ 50,000
7.	Delete paper tube void in concrete. (See Figure 38).	$ 10,367
8.	Revise roof framing and slab. (Recommended savings $97,000. Designer accepted alternate roof framing).	$ 35,069
9.	Delete intumescent paint fire proofing of structural steel.	$ 84,900
10.	Replace double concrete wall between aeration tanks and compressor building with columns.	$ 56,500
11.	Replace continuous 3 1/2 X 5 angle around roof slab with individual clips for mullion support.	$ 4,650
12.	Support crane on separate structural system; eliminate eccentric load in building structure. (See Figure 39).	$ 50,780
13.	Substitute conduit and cable for 5 KV bus ducts.	$225,000
14.	Substitute NEMA #1 General Purpose Enclosures for NEMA #12 enclosures for motor control centers and switchgear. (Recommended savings $11,000. Designer added gasketing requirement).	$ 7,500
15.	Increase spacing of vertical piles to develop full design capacity of 100 kip piles. (Recommended savings $936,353. Designer cited specific oversights, i.e., punching shear on tank slab, erroneous load assumptions, loading eccentricities to rebut some, but accepted others).	$252,157
16.	Replace non-shrink grout with cement grout.	$1,419,232
17.	Extend construction joints from 25 feet to 50 feet.	$318,196
	Contract 14, Second Stage Facilities Total Accepted Savings	$3,269,087

Rejected Suggestions (S) and Justification (J)		Savings
1.	(S) Omit continuous angle support for launder weir, and replace with individual anchor bolts, weld studs or inserts.	$380,452

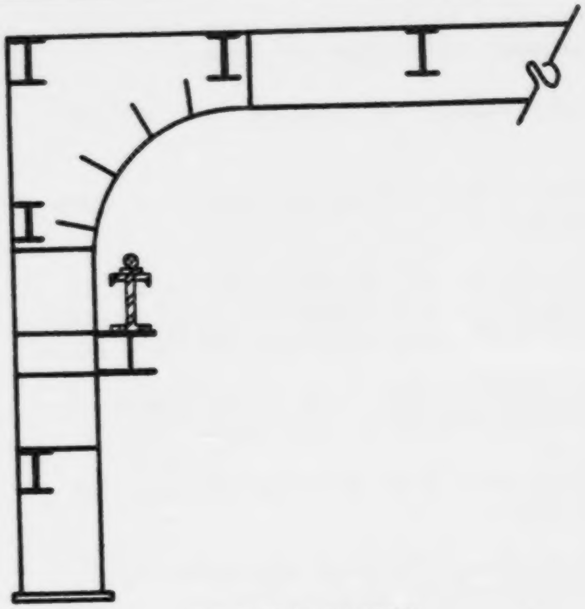

18"ø PAPER TUBE

PRESENT 18"ø PAPER TUBE

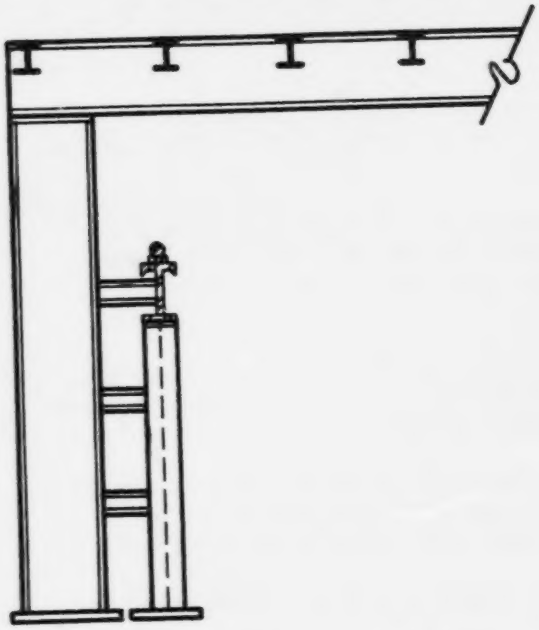


PROPOSED SOLID HAUNCH

TYPICAL TANK BAFFLE WALL HAUNCH DETAIL
FIGURE 38
CONTRACT 14, ITEM 7



PARTIAL ELEVATION



PARTIAL REVISED ELEVATION

FIGURE 39
CONTRACT 14, ITEM 12

	(J) Experience in installing such fasteners showed damaged or sheared off studs.	
2.	(S) Delete walkway on aeration tank divider wall.	$224,503
	(J) Would prevent future addition of a spray water system.	
3.	(S) Decrease all 18" aeration tank slabs to 16" thickness. Add #5 rebar at all pile caps. Add #5 bent bars, and eliminate all "hi-chairs".	$218,822
	(J) Will increase top rebar requirements, and subject bottom rebars to corrosion.	
4.	(S) Replace stainless steel aeration piping with fiberglass.	$241,760
	(J) No experience or tests available for using fiberglass in this application.	
5.	(S) Replace reinforced concrete pipe in return sludge line with cast-in-place concrete walls.	$ 68,862
	(J) Standard pipe fittings could not be used and head loss from poorer flow coefficient not acceptable.	
6.	(S) Relocate aeration tank air headers 9' lower, directly on top of tank, with steps provided for crossover at intersecting walkways.	$ 34,188
	(J) Would limit access to tanks. Air flow measuring elements would not function without existing length of pipe.	
7.	(S) Reduce backfill on South wall of aeration and settling tanks to same height as North wall. Use same wall section as North wall.	$ 43,611
	(J) Grading requirements are different.	
8.	(S) Eliminate third row of reinforcing steel in tank footings.	$ 39,864
	(J) Without center bars, tension stresses cannot be transferred from upper to lower rebars.	

9.	(S) Reduce North-South tunnel height by one foot.	$ 9,617
	(J) Clearances will be unacceptable, and overall tank geometry will be affected.	
10.	(S) Lower compressor floor by 11 1/2 feet; in turn lower building height and eliminate crane.	$103,550
	(J) Will limit access between aeration tanks; access to one half of the building blocked by air header. Headroom and access restricted in basement.	
11.	(S) Eliminate roof drain piping to storm drainage system; drain roof directly into treatment stream.	$ 18,010
	(J) Regulatory rules and ordinances prohibit discharge of storm water into waste streams on new construction.	
12.	(S) Eliminate 30 ton bridge crane.	$216,610
	(J) Maintenance would require specialized labor and rigging equipment.	
13.	(S) Limit crane travel to reduce building height.	$ 5,560
	(J) Will leave some equipment inaccessible for maintenance.	
14.	(S) Present design locates compressors in middle of building. Relocate at end of building to reduce length of piping runs.	$ 15,900
	(J) Would prevent installation of a stairway required by Cleveland Sewage District.	
15.	(S) Substitute precast concrete for steel frame of compressor building.	$ 81,300
	(J) VE team compared cost of steel frame, which is designed for heavy moment connection, with a precast construction that does not. Savings is not real.	

16. (S) Relocate entire sludge return pumping station. Reduce back fill and road work; route effluent channel straight through rather than under the building; omit two 72" dia. RCP return sludge pipes. $585,600

(J) Would block access for polymer delivery; would block access to replace spiral pumps; pump room floor would be ten feet above tops of tanks, requiring access ramps and retaining walls.

17. (S) Eliminate sluice gate on swing spare spiral pump in sludge return pump station. $ 17,800

(J) Would reduce operating flexibility of pump station.

18. (S) Omit either of two stairs in sludge pump station. $ 3,100

(J) Would violate Ohio building code.

19. (S) Eliminate bridge crane in sludge pump station. $ 56,100

(J) Survey of all existing spiral lift stations shows inclusion of cranes. Maintenance would be difficult without cranes.

20. (S) Relocate electrical substation #16. $ 4,800

(J) Any closer location would interfere with turn around area.

21. (S) Use excavation material from Contract #10 as fill in Contract #14. $457,800

(J) Contract #14 is balanced on cut and fill. Further, the VE team has recommended using this same cut material on Contract #15.

22. (S) Reduce scope of batter piles at South wall of tank #10. $277,540

(J) The grading requirements are different for North and South walls.

23. (S) Design vertical piles to accept horizontal loads, and eliminate batter piles. $893,330

	(J) To develop the necessary resistance, the piles would have to deflect one half inch. The bending stresses would exceed concrete allowables. Therefore, the steel casings would have to be designed to carry the bending. This would preclude use of shell piles, require special moment connections, and limit the installation to the use of pipe piles.	
24	(S) Use ash material to backfill foundation walls.	$194,299
	(J) The spec was incorrectly interpreted to require offsite backfill material. Current work progress shows acceptable compaction of on-site materials.	

Contract #14 , Cleveland Southerly

Totally Rejected Suggestions	$4,220,878
Total, Partially Rejected Suggestions	1,280,445
Approved Suggestions	3,269,087
Total VE Proposed	8,770,410

SUMMARY OF THE VE STUDY

Savings

At the writing of this report, the designer and the CRSD had completed their review of the VE recommendations for Contracts 10 (primary facilities) and 14 (second stage facilities). On Contract 10, $2.43 million savings were approved out of $4.72 million recommended, a 51.5% approval, for 6.5% savings. On Contract 14, $3.27 million savings were approved out of $8.77 million recommended, a 37.3% approval for a 4.4% savings. At this writing the Designer's review of Contract 15 recommendations was not complete. The average of 44% approval and 5.5% savings on the first two contracts is a very creditable result for a study with such tight constraints so late in design.

The cost of the completed portion of the Cleveland-Southerly VE study represents 0.2% of the estimated construction costs for those packages, and 4% of the savings the study generated, or a 25 to 1 return. The results of the study were sufficiently impressive to indicate that VE studies at 50% complete or later should include construction specialties on the VE teams.

General Observations

A very large part of the VE firm's expense was the preparation of a very detailed cost estimate of the 100% complete design. The VE firm characterized it as being "as accurate as if we were bidding it for construction". A substantial portion of the cost for the VE study was this estimating effort. It should be recognized that reliable cost information is essential for an effective VE analysis. However, the VE effort in cost information gathering should be limited to verifying the designer's data.

The VE reports for each of the three studies were quite large, and well illustrated, but due to the forms used, the same information was presented repeatedly. This made the report large and lengthy for a reviewer (Designer, Owner, State, EPA) to read. A few such forms are useful during the course of a VE study, to insure that unrecorded ideas are not lost, and that all are subjected to the same degree of analysis, but the final form of the report should be concise in presentation. A uniform numbering system for recommendations must be adhered to so that all readers can follow and compare costs and comments readily.

The Designer expressed a preference for dealing with a single firm to VE his designs, rather than a consortium of experts from across the country. He felt strongly that team members should have experience with wastewater facilities. He felt that he could provide a ±10% estimate of costs at the 20% design complete point for future Step 2 VE studies. This would be a tops-down, ($/mgd) not a bottoms-up ($/cu yd x cu yds) estimate. The VETC commented that he would only be interested in performing VE as a prime consultant to the Owner, and not as a subcontractor to the Designer.

A very strong force for minimizing changes in the existing design was the prospect of losing grant funds if spending were to be delayed beyond normal grant expiration dates. The Ohio EPA indicated that since there was a mechanism for freezing grant funds when a delay results from, for example, a citizen or losing-bidder lawsuit, there should be a similar mechanism for delays to achieve economy.

INDIANAPOLIS, INDIANA PROJECT

This section is based on interviews held during November and December, 1976 with the design firm, the VE consultant, the City, and the State Board of Health & Water Pollution.

Visits to both of the treatment plants involved in the study and visits to some of the workshop sessions were made.

Description of the Proposed Project Prior to the VE Study

The City of Indianapolis presently operates two large secondary treatment plants. These are known as the Belmont Plant and the Southport Plant (Figures 40 and 41). Both plants use the activated sludge process and discharge into the White River. Sludge from both plants is treated and incinerated at the Belmont plant by conditioning with ash from the incinerators, dewatering on vacuum filters and burning in multiple hearth incinerators.

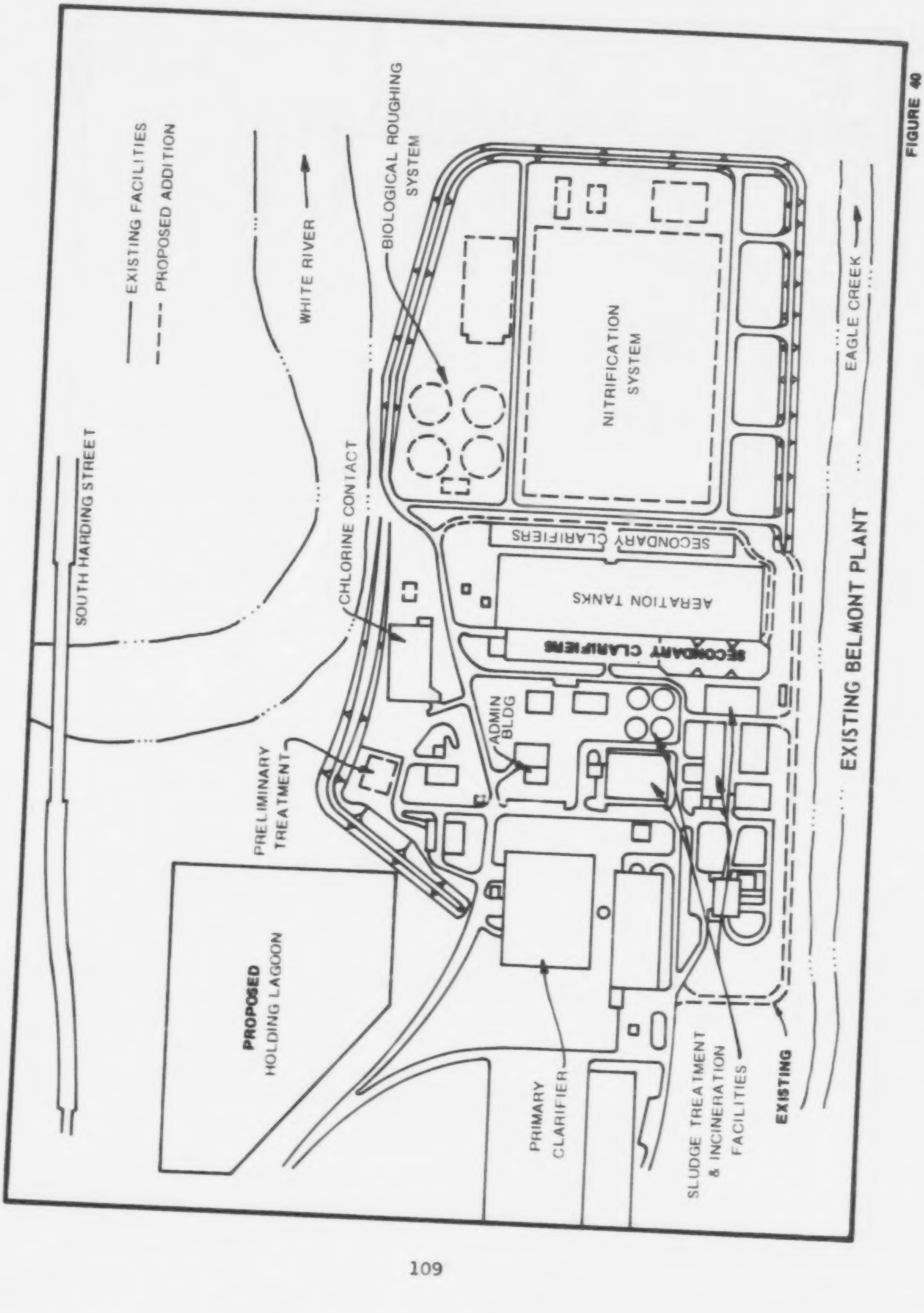

EXISTING FACILITIES
PROPOSED ADDITION
SOUTH HARDING STREET
WHITE RIVER
CHLORINE CONTACT
BIOLOGICAL ROUGHING SYSTEM
NITRIFICATION SYSTEM
SECONDARY CLARIFIERS
AERATION TANKS
SECONDARY CLARIFIERS
ADMIN BLDG
PRELIMINARY TREATMENT
PROPOSED
HOLDING LAGOON
PRIMARY CLARIFIER
SLUDGE TREATMENT & INCINERATION FACILITIES
EXISTING
EAGLE CREEK
EXISTING BELMONT PLANT

FIGURE 40

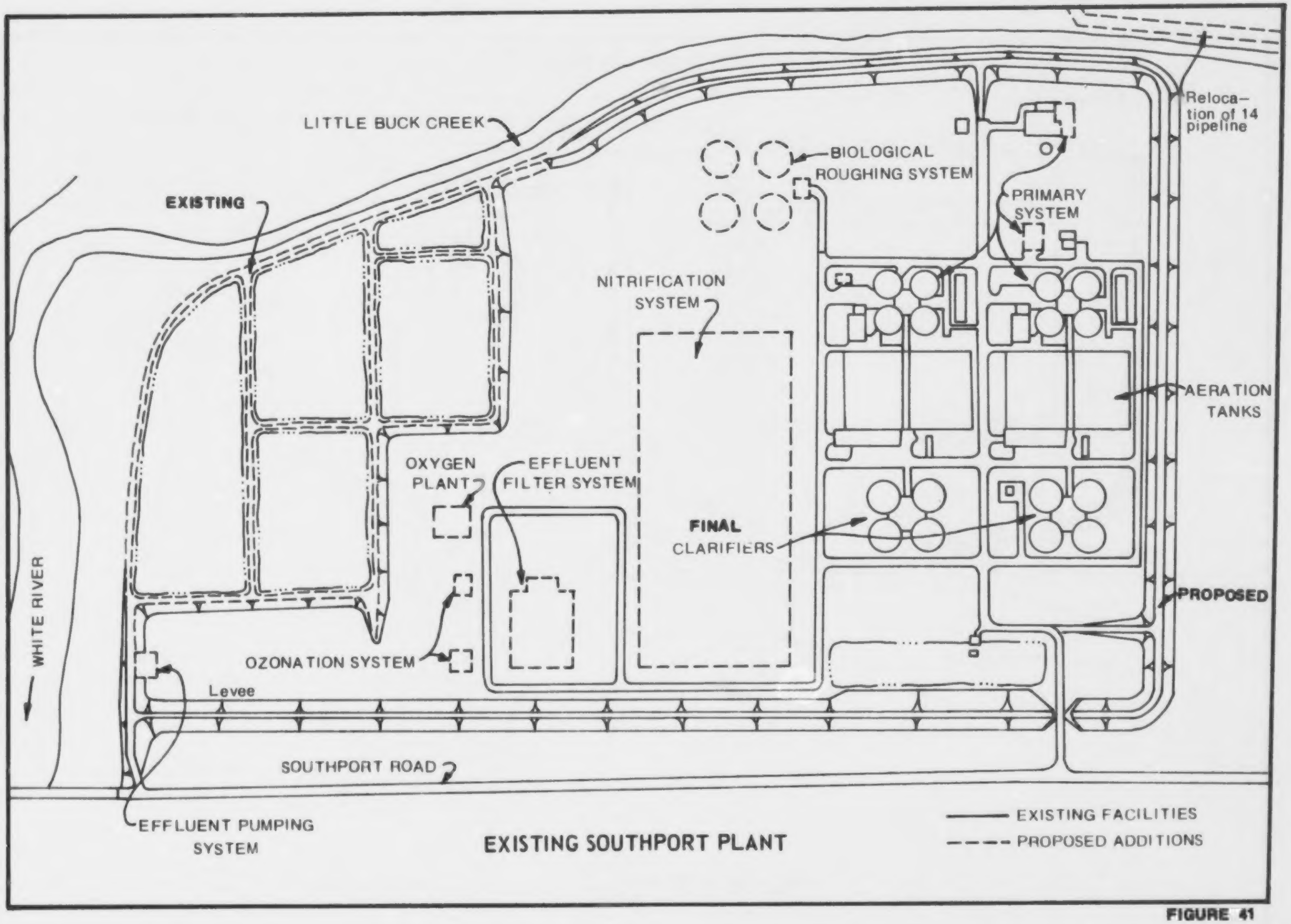

LITTLE BUCK CREEK
EXISTING
BIOLOGICAL ROUGHING SYSTEM
Reloca-tion of 14 pipeline
PRIMARY SYSTEM
NITRIFICATION SYSTEM
AERATION TANKS
OXYGEN PLANT
EFFLUENT FILTER SYSTEM
FINAL CLARIFIERS
WHITE RIVER
PROPOSED
OZONATION SYSTEM
Levee
SOUTHPORT ROAD
EFFLUENT PUMPING SYSTEM
EXISTING SOUTHPORT PLANT
EXISTING FACILITIES
PROPOSED ADDITIONS

FIGURE 41

The Belmont plant, largest of the two, was built in several stages beginning in 1925. This plant has a peak primary capacity of 285 mgd and a secondary capacity of 125 mgd. The newer Southport plant has a capacity of 56 mgd. This plant was built as two parallel 28 mgd trains, one train in 1966 and the other in 1969.

In 1972 the Indiana Pollution Control Board issued an order calling for the plants to be upgraded to provide an advanced level of treatment and issued new discharge standards. These discharge standards required an effluent quality as follows:

Biochemical Oxygen Demand (5-day)	10 mg/l
Suspended Solids	10 mg/l
Ammonia Nitrogen	1 mg/l
Dissolved Oxygen	8 mg/l

These standards were predicated on the fact that during low flow stages in the river, effluent flow is several times the river flow. An extensive pilot study was completed and a facilities plan recommending the treatment process was then prepared. The facilities plan recommended the following process for the Belmont plant:

1. Install new screens and grit chambers
2. Reequip and modernize the existing raw sewage pump station
3. Construct fixed-film roughing towers
4. Construct oxygen activated sludge nitrification facilities and a cryogenic oxygen generating system
5. Construct a gravity filtration system
6. Construct an ozone disinfection/post oxygenation system

Many of the older facilities including aeration basins, secondary clarifiers and blowers were to be abandoned. One blower building was to remain as a storage building. Little work on the existing sludge handling system was proposed under the plan.

Work proposed at the Belmont plant also included construction of new laboratory facilities, a new computerized control system and a new employee facility. A layout of the proposed facilities is shown in Figure 40.

Although the discharge requirements and the flow sheet proposed for the Southport plant were basically the same as for the Belmont plant, because of its relative newness, recommended construction differed somewhat. The plan for the preliminary/primary treatment system called for construction of new preliminary treatment facilities (screening and aerated grit removal), modification of existing circular primary clarifiers to accomodate higher flows, and refitting of the existing primary pump station. Following primary treatment, fixed-film roughing on plastic or redwood media filters was planned. This was to be followed by suspended growth nitrification using a pure oxygen retrofit of existing aeration tanks.

New rectangular secondary clarifiers with related return and waste sludge systems were proposed to accomodate the nitrification system. The plan then called for filtration of the effluent in gravity filters and disinfection and oxygenation of the final effluent with ozone (Figure 42).

The existing shallow and inefficient secondary clarifiers were to be abandoned and the blower buildings were to be converted to a laboratory and a maintenance building.

The pre VE cost for enlarging and upgrading the two plants was estimated to be $234,000,000.

The VE Study

Background--

In March, 1975, the prime design firm began preparation of plans and specifications for construction of the two plants. The design schedule called for the plants to be operational by January, 1979. The time limit and the size of the project called for separate construction contracts to be let for various parts of the work as its design was completed and also to let separate contracts for purchase of some of the larger equipment orders.

The schedule also necessitated that the designer subcontract some of the design to other firms. Several local and regional firms were then contacted and assigned phases of the work.

Design proceeded on schedule and by September, 1975 contracts for the sitework at both plants and for purchase of the cryogenic oxygen generating equipment were advertised for bids. Design for other portions of the work was also progressing - some phases nearing completion and some just getting started.

Over the several year life the project had experienced, costs had risen considerable. With each update of the facilities plan, new requirements and inflation caused estimated costs to rise. This increase in cost and the fact that much of the Belmont plant, even though old, was proposed for abandonment, caused the State to be concerned and to look for ways to reduce costs. After discussion with EPA, the State suggested to the City that a voluntary Value Engineering study of the design would benefit all concerned. The City expressed concern that such a study would delay the project and result in a failure to meet the 1979 deadline for operation of the new plants. However, the City agreed to proceed with Value Engineering and in October, 1975 requested proposals for the work. In March, 1976 a tentative grant award was received from EPA and meetings between the City and the selected VE consultants were held to organize the study.

At the beginning of the VE study, design had progressed to the point where much of the design, including the nitrification systems, effluent filters and the Belmont accessory buildings was complete and ready for bid. The completion of other work ranged from 5 to 90 percent.

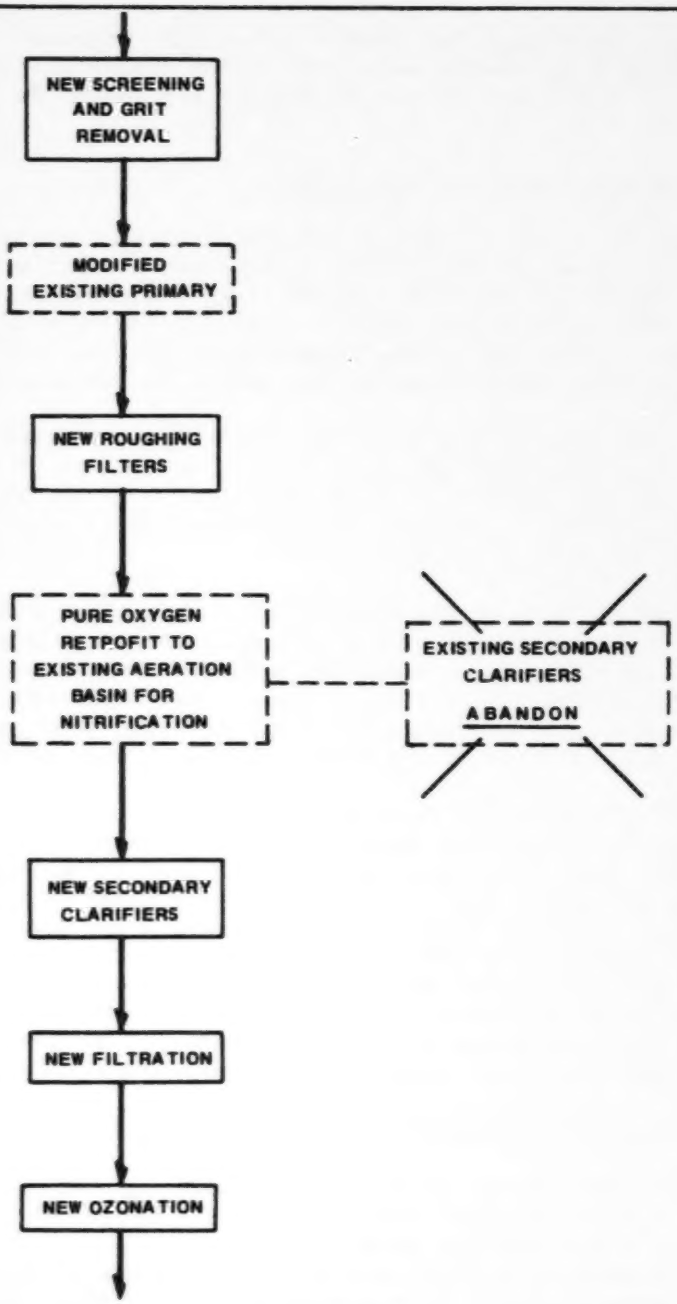

NEW SCREENING AND GRIT REMOVAL
MODIFIED EXISTING PRIMARY
NEW ROUGHING FILTERS
PURE OXYGEN RETROFIT TO EXISTING AERATION BASIN FOR NITRIFICATION
EXISTING SECONDARY CLARIFIERS
ABANDON
NEW SECONDARY CLARIFIERS
NEW FILTRATION
NEW OZONATION

Figure 42

PROPOSED SOUTHPORT
FLOW SCHEMATIC

It was also during that period and on into February, 1976 that re-evaluations of some systems were made by the designers. These included re-evaluation of whether or not to abandon the Southport activated sludge tanks.

Organization and Conduct of the Study

Discussion of the study's organization must be prefaced by mention or reiteration of some of the factors controlling and influencing it. First, were the reasons for the voluntary VE study. Although the main reason for the study was to reduce the project's cost, there were underlying reasons for it also. For example, the State did not believe that they had sufficiently qualified staff to accomplish review of the project.

The desire for a general review of the design influenced the selection of the VE consultant and the study itself. All three of the VE consultants considered for the work were teams made up of a large, recognized sanitary engineering firm with experience in designing large plants and a firm experienced in value engineering.

Because the project was to be divided into several contracts and because the designs for some of the contracts were much further along than for others, the City decided to divide the VE study into phases in order to complete certain portions at an early date. This was to allow changes to be made and contracts to be let early for the construction needed first. Table 9 shows a listing of the work included in each of the three phases.

The City limited the VE study further by selecting only portions of the project for review and imposing a list of constraints. Systems representing only about 60 percent of the total cost (those shown in Table 9) were to be reviewed. Some systems which were nearly identical for the two plants, e.g., effluent filters, roughing towers and disinfection facilities, were to be studied only once. Systems for which savings in comparison to overall plant costs were expected to be small and over which there was no controversy were also left out of the VE study. The VETC remarked that in effect the City performed an informal functional analysis prior to the study and excluded those elements with minor potential for savings.

The constraints imposed by the City included:

1. Certain design parameters are fixed
2. Process has been fixed
3. Effluent quality criteria are fixed
4. Alternatives which unduly extend the design and construction schedule shall be de-emphasized unless there are substantial present worth savings which would justify delay in plant startup.
5. All alternatives shall comply with all State and EPA directives, regulations and guidelines.
6. Equivalent of secondary treatment must be maintained at all times at both plants.

TABLE 9

OUTLINE OF V.E. TASKS

FACILITY

Phase I

Belmont
- Nitrification System (include review of abandonment of aeration tanks and final clarifiers).

Southport
- Nitrification System (include review of abandonment of final clarifiers at the Southport Plant).
- Intermediate Pump Station.

Phase II

Belmont
- Primary System including bar screens, grit chambers, raw pump station and primary clarifiers (include review of increasing capacity of the primary from 220 mgd to 300 mgd independent of Phase I, and review of the proposed modification of pumping station).
- Stormwater Holding/Equalization Lagoon (include review of the location of holding lagoon inlet at outlet of primary settling tanks).
- Roughing System.

Southport
- Yard Piping.
- Primary System including bar screens, influent pumping stations, grit chambers, and primary clarifiers.
- Ozone System.

Phase III

Belmont
- Electrical Distribution System including Substation.
- Laboratory Building, reuse of blower building, remodel administration building (include review of space and cost requirements for new laboratory/administration building and possible modification of present administration and blower building (office/storage).

Southport
- Effluent Pumping Station.
- Effluent Filters.
- Electrical Distribution System including Substations.

A seventh constraint requiring that the study be conducted in Indianapolis was dropped. The City did indicate at the end of the project that if they were ever again involved in a VE study, they would be sure it was done in Indianapolis to ease transfer of information.

With the exception of No. 2, the constraints posed no problem to the study and were readily accepted by the VE consultant. Constraint 2, however, was a source of almost constant conflict over what was meant by "process" and "fixed".

As previously mentioned, pilot studies had been conducted on a number of processes and combinations of processes. These studies were instrumental in selecting the process train adopted for the two plants. As a result, there was much reluctance on the parts of the City and designer to allow any variation of the process. On the other hand, the VE consultnat was charged with review of the abandonment of facilities and equipment, while achieving the greatest possible saving but with the design unchanged in general. One group said that roughing on plastic media, single-stage nitrification with high purity oxygen and disinfection with ozone as well as all the designers loading rates must remain unchanged. The other group said that consideration of different roughing techniques, using air instead of oxygen in the activated sludge process, two stage nitrification, disinfection with chlorine and a number of other modifications to the design could possibly produce savings without affecting the effluent quality and should be subjected to study. As the study progressed, some compromises were reached and some process changes were considered and recommended by the VE consultant.

Actual work on the VE study began with a day long briefing attended by representatives of the designer and his subcontractors, the City, the State, EPA, the VE consultant and several team members, and others. Representatives of the City, State and the designer gave the history of the project, presented much of the available reference materials and explained the background of some of the discussion made during design. The meeting was preceeded by two days of tours of the plants to gain a better knowledge of the layout and condition of facilities, and to provide team members a chance to talk with operating personnel. Both of these familiarization processes are now considered "musts" by the VETC.

The workshops for this project were not conducted in the typical 40-hour-straight-through sessions. They were, however, conducted in the normal informational, creative, analytical and proposal phases. With some variation, a team would meet and in one or two days conduct the informational, creative, and part of the analytical sessions. The team would then adjourn and the members would individually complete assigned portions of the remainder of the analytical work (including estimating) and portions of the proposal work. In some instances the remainder of the proposal was completed in reconvened team meetings, but in others, they were completed by individual assignment.

Adjourning the team in order to complete the analytical work was perhaps necessary in some instances. Because of the magnitude and complexity of some of the tasks being studied, considerably more than the normal one to two days usually devoted to analysis of alternatives was necessary.

Teams used in the study were multidisciplinary and were drawn from a list of some thirty-five individuals representing both members of the two firms doing the VE study. Members were primarily professional engineers and architects and represented such engineering disciplines as sanitary, mechanical, industrial, electrical, chemical, instrumentation, civil and structural. The preponderance of the participants were sanitary and structural engineers, however, many could be considered to represent more than one specialty.

Teams ranged in size from five members up to eleven or twelve members depending on the size and complexity of the team assignment. It should be noted that often assignments considered total systems such as nitrification rather than specialties such as structures and this possibly resulted in the use of larger teams having more disciplines, rather than greater numbers of smaller teams. Because of the phasing some of the participants served on more than one team.

Presentation of the results of each phase was done in three parts. At the mid-point of each phase an in-progress review was held to allow the VE consultant to present to the designer and City the alternates he was considering and to receive some feedback as to their acceptability. An end-of-phase briefing was held when work for the particular phase was about 90 percent complete to present findings and make sure proposed alternatives were understood. This briefing was followed by presentation of a final report for the phase. When the entire study was completed, a final presentation was made to summarize the findings of the three phases.

The designer's role during the study was primarily to provide information and to evaluate proposed alternatives. As mentioned, the designer was present at the initial briefing session and at the presentation made by the VE consultant.

For a project of the nature of the Indianapolis plant there was a vast amount of data and knowledge to be transferred and interpreted. This transfer of information was complicated further because most of the VE study was conducted at the office of the VETC in St. Louis, while the designer was in Indianapolis.

Some of the work was also done in the Chicago office of one of the VE consultant members. The designer stated that had the VE study been conducted in Indianapolis as originally planned, information transfer would have been more effective as well as more efficient. He also thought that would he have been closer to the study he could have prevented time from being wasted studying alternatives he had already considered in some detail. However, the City felt that no project delays were attributable to the value engineering process at the mid-point of the study and a decision was made to continue VE. On receipt of the reports from the VE consultant, the designer made a review of all proposed alternatives and then prepared his final report accepting or rejecting those alternatives. The designer stated he had to re-estimate the costs of some 71 VE recommendations in order to have costs comparable to original estimates.

The City's role was one of coordinating, resolving conflicts, expediting, and trying to keep the project on schedule. On completion of the study the City began reviewing proposals from the VE consultant's and the designer's final reports and re-evaluating some of the alternatives rejected by the designer. No follow-up work to review and push further alternates rejected by the designer was provided for in the VE contract. The City's representative, however, has had a considerable amount of design experience and, within the limits of his available time, is qualified to review them himself. The City made suggestions which were adopted, providing significant savings.

The State's active involvement in the VE process had substantial impact on the scope of the VE analysis and subsequently on the level of VE effort. The State now considers it desirable to have the VE consultant review and comment on the designer's report and then meet with the designer to make one last try to resolve differences. Both the State and the City said, however, that if additional time was taken for further review, the projects position on the funding priority list would be lost for the current year. Both recommended that some means be developed by EPA whereby current year funding for a project could be frozen without being lost.

Level of Effort

The cost for the VE study was $349,400 or about 0.15 percent of the total estimated construction cost for the two plants. Of the total cost for the study, $275,000 was for the VE consultant and $74,400 was for assistance and review by the designer. The above costs, however, do not reflect the considerable amount of time spent by the City during the study.

When the study was conceived, it was proposed to run the three phases in succession using three teams for the first phase and six teams each for the two remaining phase. Each phase was to take a maximum of three months from its beginning to delivery of its final report with the final report for phase 3 being submitted September 14, 1976.

There was considerable variance to the team make-up and schedule. The final report for phase 3 was submitted on October 18, 1976. The designers final report was issued on November 12, 1976.

Summary of Savings and Recommendations

Savings listed in the VE consultant's final report total $43,600,000 in initial cost and $43,472,000 in present worth, life-cycle cost over 20 years. Savings from recommendations accepted by the designer total $21,918,000 in initial cost and $22,969,000 in present worth, life-cycle cost. The designer claims that $12,600,000 of the initial savings and $13,500,000 in life-cycle savings are the result of a suggestion he made prior to the VE process to use an all new nitrification system at the Southport plant. Recognizing this, savings from VE effort would be $9,318,000 and $9,469,000 respectively for initial and life-cycle costs. Table 10 summarizes the savings anticipated from accepted recommendations and Table 11 summarizes rejected recommendations.

The initial studies under phase I concentrated on the nitrification systems and whether or not to abandon existing facilities. Various changes such as the use of air rather than oxygen and the use of single or two stage nitrification rather than the designed roughing/nitrification system were also evaluated.

The results of this early work were three alternate systems for Southport all judged by the VE team to be more cost effective than the designed system. These alternates were:

1. Split the primary effluent such that 70 mgd would flow through new roughing filters, new nitrification tanks and new clarifiers and the remaining 55 mgd would flow through the existing facilities. Flows would be recombined before the effluent filters (Figure 43).

2. Split the primary effluent such that 70 mgd would flow through new roughing filters. The remaining 55 mgd would be roughed in the existing activated sludge plant. Flows would then be recombined and flow to new nitrification tanks and on through the remainder of the process (Figure 44).

3. Pump the entire primary effluent flow through new roughing filters and then split it such that 50 mgd would be nitrified in the existing air activated sludge plant and the remaining 75 mgd would be nitrified in a new oxygen nitrification system. Flows would then be recombined and pass to new final clarifiers and on through the remainder of the plant (Figure 45).

The City judged alternates 1 and 3 to be unallowable process changes and these alternates were dropped from the study. Alternate 2 (split roughing) was judged acceptable and set the basis for continuation of the study. The prime constraints on process change seemed to be that any new system must provide some form of roughing and that nitrification must be accomplished by using pure-oxygen, activated sludge facilities for the entire flow. Later, disinfection and post-aeration with ozone was added to the "required" list. The split roughing concept was later also proposed for the Belmont plant. Savings anticipated from split roughing Belmont were estimated to be: Initial costs - $4,810,000 and Annual LC costs - $150,300. The designer rejected the split roughing concept for both plants. In his final report the designer accepted a concept of split nitrification.

In all, the VE reports for the Indianapolis project include four large

TABLE 10

ACCEPTED VE RECOMMENDATIONS - INDIANAPOLIS

	Initial	LCC - Present Worth
Split Nitrification at Southport - 30 mgd Through Existing Facilities, 95 mgd to all New Nitrification (Oxygen) Facility; Modified Version of an Idea Submitted by Designer Prior to VE Workshop(1)	$17,860,000	$17,714,000
Modify Piping Gallery, Screw Pumps, Clarifiers		
Belmont	1,226,000	1,793,000
Southport	981,000	1,435,000
Use Straight Weirs on Primary Clarifiers Instead of Installing Serpentine Weirs (Southport)	134,000	234,000
Replace Effluent Pump Station Electric Motors With Diesel Power (Southport)	240,000	238,000
Eliminate Roofs Over Effluent Filters (Belmont and Southport) While Retaining Roof Over Operating Gallery	416,000	416,000
Relocate Laboratory Building and Remodel Existing Administration Building	881,000	959,000
	$21,918,000	$22,969,000
(1) Portion of savings resulting from suggestion by Designer prior to VE Workshop	12,600,000	13,500,000
Net savings attributable to VE effort by Designer, City, and VE Consultants	$ 9,318,000	$ 9,469,000

TABLE 11

REJECTED VE IDEAS

Item	Reason for Rejection
(Several items associated with original concept of retrofitting existing aeration basins at Southport with oxygen system to provide nitrification were rendered obsolete by the decision to construct new nitrification facilities for 95 mgd and use existing basins for nitrification of 30 mgd. These items are not listed here.)	
Locate ozone generation building on top of ozone contact tank.	Would require more costly contact tank structure. Could cause safety hazard if leaks develop in tank top.
Separate ozone equipment into 3 groups and house in separate buildings around perimeter of contact tanks in buildings with 2 or more open sides.	Open sides provide no shelter during wet weather. O & M more difficult if system is fragmented. Piping costs would increase due to out units.
Eliminate louvers around ozone generator section of ozone building (leave building open) or replace with screens.	Provides no weather protection.
Use existing Southport bar screens with new facility for one screen.	Existing screens are maintenance problem, bars are bent, chains break often, grinder inoperable.
Replace bar screens with new rear cleaning devices with new building for one added screen.	Proposed construction very difficult. Could not find manufacturer who could supply screen as proposed. Velocities would be excessive. Cost estimate too low when all associated costs to existing building considered.
Use existing grit chambers.	Hydraulics inadequate. Eliminates desired redundancy.
Use velocity controlled grit chamber in place of aerated grit chamber.	Potential odor problems. Larger structures would be more costly than proposed design.
Provide primary treatment at Belmont of portion of flow to Southport plant.	Costs of transfer line underestimated by VE. Would reduce storm flow treatment at Belmont.

TABLE 11
(continued)

Item	Reason for Rejection
Provide electric drive for all pumps with diesel generators for standby power.	Inadequate number of generators contained in VE recommendation.
Replace axial flow pumps with screw pumps.	Not as cost effective as diesel power for pumps (see accepted ideas in Table 2).
Use single surface wash arm in effluent filters instead of dual arm.	Loss of cleaning capability. Power savings could be offset by need for longer backwashing.
Move filter flumes from center of each filter to end.	Would increase head for backwash, requiring increase in bw pumps from 500 to 1000 HP.
Eliminate backwash surge relief valves.	Design had already been modified to eliminate two of the valves.
Eliminate redundant valving in surface wash system.	Pump shut-off valves needed to isolate pumps for service, throttling valves needed to control flow, filter shut-off valves needed to isolate filter for wash cycle.
Use insert flow tubes rather than magnetic flow meters for spent filter washwater flow monitoring.	Solids would plug sensing apertures in insert flow tube.
Eliminate air relief valves on surface wash, backwash, and spent washwater lines.	Valve on spent washwater line eliminated. Others needed to prevent upset of filter media.
Eliminate filter surface wash flow rate control system.	Need to adjust flow to keep volume of spent washwater as low as possible. Also used to control amount of chlorine injected.
Eliminate utility water flow monitoring system.	Need to determine amount of chlorine to feed to filter effluent used in the plant and to determine pump or valve failures.
Use 2300 V. power source and control pump speed with magnetic couplings.	Variable frequency drives more efficient. Magnetic coupling costs used in VE are low and exclude some needed items.

TABLE 11
(continued)

Item	Reason for Rejection
Maintain underground dual line primary and secondary electrical service but use 2400 V. service for larger motors.	Transformers used in VE not stock items and costs used in VE are low; double transformation losses not considered; increases safety hazards.

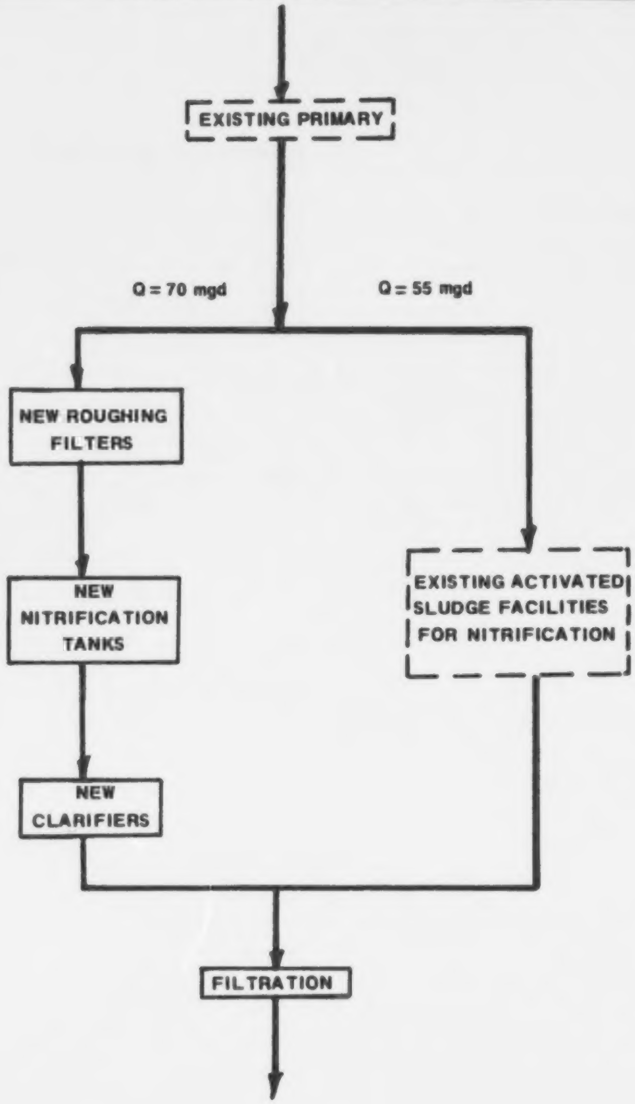

EXISTING PRIMARY
Q = 70 mgd
Q = 55 mgd
NEW ROUGHING FILTERS
NEW NITRIFICATION TANKS
NEW CLARIFIERS
EXISTING ACTIVATED SLUDGE FACILITIES FOR NITRIFICATION
FILTRATION

Figure 43

TREATMENT ALTERNATIVE ONE–
SOUTHPORT

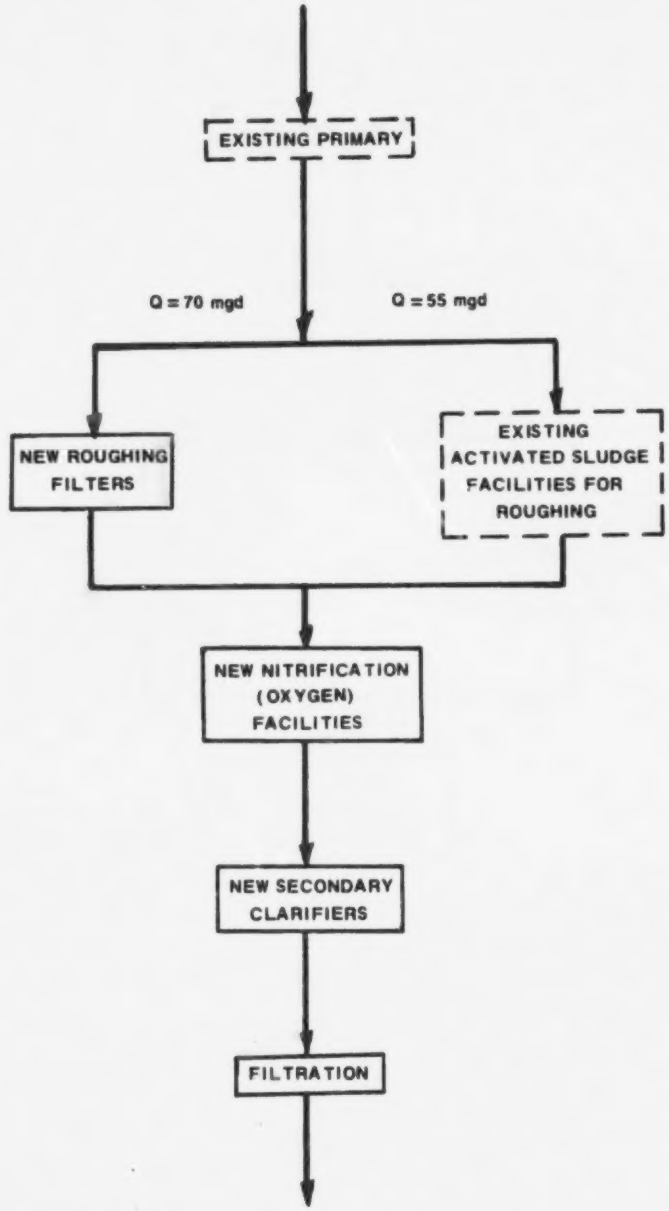

EXISTING PRIMARY
Q = 70 mgd
Q = 55 mgd
NEW ROUGHING FILTERS
EXISTING ACTIVATED SLUDGE FACILITIES FOR ROUGHING
NEW NITRIFICATION (OXYGEN) FACILITIES
NEW SECONDARY CLARIFIERS
FILTRATION

Figure 44

TREATMENT (SPLIT ROUGHING) ALTERNATIVE TWO–SOUTHPORT

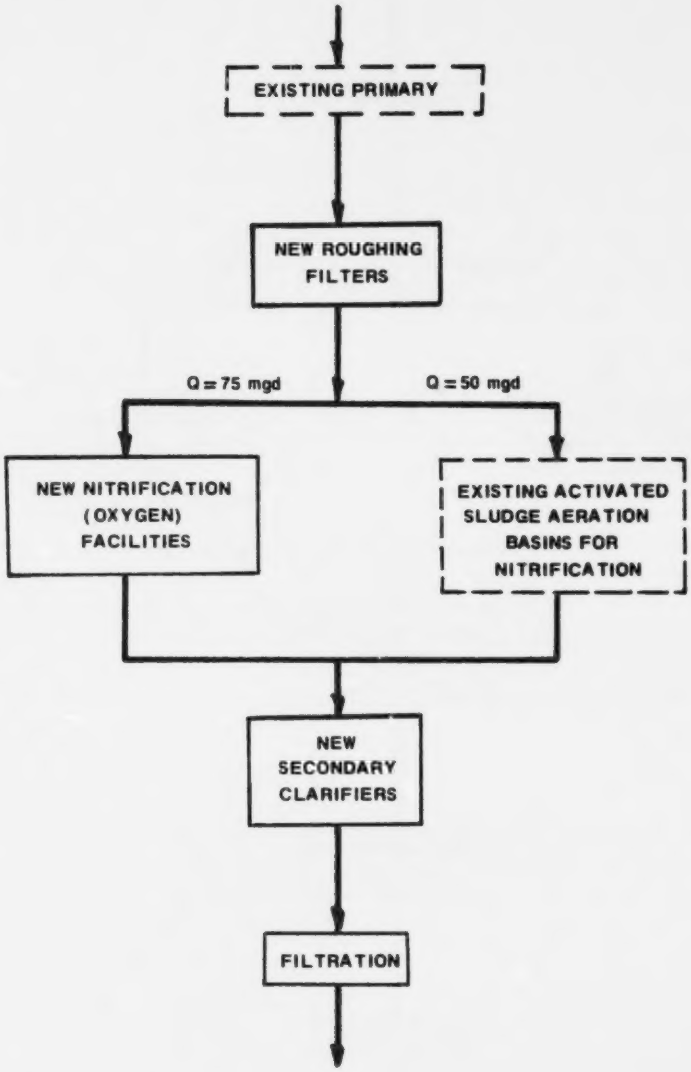

EXISTING PRIMARY
NEW ROUGHING FILTERS
Q = 75 mgd
Q = 50 mgd
NEW NITRIFICATION (OXYGEN) FACILITIES
EXISTING ACTIVATED SLUDGE AERATION BASINS FOR NITRIFICATION
NEW SECONDARY CLARIFIERS
FILTRATION

Figure 45

TREATMENT ALTERNATIVE THREE–
SOUTHPORT

volumes of suggestions and supporting analysis prepared by the VE consultant. One large volume was prepared by the designer which contained his supporting determinations of the acceptability of the VE suggestions.

General Comments

On such a major project, the study should be conducted locally so that the designer can provide needed assistance. By having the sessions conducted locally, the designer would (1) be available in person to explain the project and his work, and (2) to keep better informed of the ideas being proposed and thus be able to indicate what alternates he may already have reviewed and rejected during design.

When delay from redesign time results from VE, the cost of inflation should be included in the comparisons of costs for proposed alternatives.

For the Indianapolis project, the Designer expressed that time could have been saved if he had had more opportunity to explain his cost estimates.

The designer has more confidence in his design as a result of the VE procedure.

The State believed that no grants should be awarded for VE until a good cost estimate is available. Guidance on inflation rates for plant and power costs, design life and interest rates, etc. should be given by EPA in a manner similar to that for facilities planning. All criteria controlling the VE study need to be fixed and clearly spelled out. The VETC should be present in final meetings and have previously had time to review the Designer's rebuttal. It would be beneficial to have State people on the VE teams but time and budgets may not permit it.

The City also felt that the workshops should be held locally and that team members must have no demands on their time other than the VE study. They also felt that everyone involved must understand and recognize the frailties of human nature. The City felt it is the savings that are important, not who gets the credit for them. The VETC should have a chance to participate in discussion of the Designer's rebuttals. The City and EPA agreed that the entire Indianapolis VE study should have been done at a much faster rate. There needs to be a way to gain time to evaluate ideas rejected by the Designer but which appear to have merit, without losing the current year's grant position.

The VETC believed the fact that one of the study's main purposes, which was to review the design, changed the procedures from those used in a true VE study. Much more time than would normally be allocated to analysis was spent in order to thoroughly study some alternates. The philosophy of "there must be a better way" must be considered in selecting participants. VETC work should not end when his report is presented. He must also be involved in gaining acceptance of his proposed changes. Phasing of the study is not beneficial; evaluation of ideas by the VE team created in a late phase may be influenced by biases and opinions of what might be the acceptance of the Designer of related ideas developed earlier.

GENERAL OBSERVATIONS FROM CASE STUDIES

Table 12 summarizes data on the five case studies. The return in terms of net savings to VE costs ranged from a factor of 5 to 26. VE fees ranged from about 0.2 to 0.8% of the estimated construction costs. Based upon the discussions held with the participants in these five studies and the subsequent author's analysis, the following observations are offered. An attempt is made to avoid duplication of concepts already expressed in the VE workbook although some of the observations serve to reinforce or give greater emphasis to concepts in the workbook.

1. Availability of adequate cost data on the proposed design at the start of the VE workshop is essential if the VE study returns are to be optimized. The lack of adequate cost data hampered the effectiveness of several of the VE studies analyzed. Also, lack of consistency in cost estimating techniques between the designer and VE teams created needless duplication of effort in some cases. The design work plan should recognize the necessity for cost information for VE purposes. The work plan should insure that preliminary estimates of unit quantities and unit prices are available prior to the VE workshop. The proposal for the VE study should be required to demonstrate how the availability of adequate cost data will be assured and that the VE teams will not spend their time developing basic cost information on the existing design which should be provided by the designer.

2. Another problem area is the accurate estimation of cost for a large number of alternatives in the short time available in the VE effort. Changes in unit quantities of concrete, steel, earthwork, etc., are relatively easy to evaluate. The original designers unit prices, if valid, then permit ready calculations of changes in cost. However, alternatives in process equipment not fully considered in the original design (fluidized bed incineration versus multiple hearth, for example) are much more difficult to accurately estimate and reliance on manufacturers estimates may lead to faulty conclusions. Outline specifications, at least, from the designer are needed to accurately interpret his intent. Publication of a comprehensive cost guide should be considered. Frequent use of the earlier 1971 Black & Veatch study (EPA Contract 14-12-462) was noted in the case studies but this study is difficult to up-date for some costs and does not include some recently introduced processes and equipment.

3. To avoid the common problem of having time to estimate the costs of complex alternates during the study, these alternates can often be anticipated by the VETC and designer during the

TABLE 12

SUMMARY DATA ON FIVE CASE STUDIES

		Savings				VE Investment		
	Estimated Construction Cost (Pre-VE)	Rec. Initial Savings By VE Teams	Est. Net Initial Savings of Implemented Ideas	Imp. Savings / Rec. Savings	Imp. Savings / VE Costs	VE Study Fee	% of Const. Cost	Timing of Study (% Design Completion) & No. of Teams
Lebanon, OR (3 mgd)	$3,565,000	$547,467	$274,770	0.5	9.3	$29,500	0.8	15% - 1 team 25% - 2 teams + 1 review team
Concord, N.C. (24 mgd)	$30,258,725	$3,843,570	$920,000	0.24	26.9	$34,220	0.18	75% - 1 team
Plainville, CT (3.8 mgd)	$7,550,000	$1,404,872	$1,000,000	0.71	18.6	$53,610[1]	0.7	15% - 5 teams 75% - 3 teams
Cleveland, OH (200 mgd)	$107,189,000[2]	$13,604,649	$5,700,000	0.42	23.9	$238,800	0.22	100% - 5 teams
Indianapolis, IN (250 mgd)	$234,000,000[2]	$43,600,000	$9,318,000	0.21	26.7	$349,400	0.15	Portions varied from 5 - 100%, 15 teams

[1] Grant eligible portion of VE fee - excludes training costs

[2] Cost of those portions of plant subjected to VE

preworkshop period and critical cost information for the team gathered before the workshop.

4. The constraints of the VE study (i.e., effluent criteria not to be challenged, etc.) must be clearly identified in writing as part of the proposal for the VE study. No verbal modifications of the constraints should be allowed. Major changes in constraints should require the written approval of the Owner, State and EPA prior to the VE workshop. Any uncertainties over the meaning of the constraints must be resolved before the VE workshop.

5. When the VE effort is conducted by a VETC from outside the design firm, having the VETC as a subcontractor to the designer may be an administrative convenience. However, such an arrangement has the disadvantage of placing the VETC in a subservient position to the designer. The VETC may feel an ethical limitation on the pursuit of design changes directly with the Owner, no matter how worthwhile the changes appear to be or how arbitrary the Designer's rejection of the proposal may have been. Although the advice of the designer should be sought in selecting the VETC and team members, the Owner should be encouraged to contract directly with the VETC for the VE study.

6. The VE contract should include specific provisions for participation on an as-needed basis of the VETC (and some team members if necessary) in post-VE report discussions of VE recommendations. Although the VE workbook stresses this point, in the cases observed there was no provision for participation of the VETC once the VE report had been submitted in some of the case studies. The implementation phase participation of the VETC and team members could be provided for in the VE contract as a service beyond the basic VE effort to be provided upon authorization by the Owner and reimbursed upon an hourly rate basis.

7. Participation of qualified Owner's personnel as VE team members is encouraged. Not only do they offer a useful perspective, the knowledge they gain of the proposed facilities during the VE effort will pay long term dividends to the public.

8. Careful screening of the VE team members qualifications can not be over emphasized. Several instances were observed where substantial amounts of VE workshop time were devoted to justifying the VE approach, to establishing the scope of the VE effort, and to lengthy pursuit of ideas which were simply not suited to wastewater situations.

9. Widely divergent opinions were heard on the relative desirability of one-firm outside VE efforts as opposed to the no-two-people-from-the-same firm approach. In some cases, multiple personnel from the same firm brought previously established antagonisms to the VE team, as well as the potential that their firm's bias for certain design approaches may be unduly weighed in the VE

effort. Some expressed a strong belief that the efficiencies in communication and administration by having the VE personnel all from one firm were important to a successful effort. The key to the success does not seem to hinge on the one-firm or multiple-firm composition of the VE teams but rather on the competence and objectivity of the individuals involved.

10. There were (and will, no doubt continue to be) occasions where the VE personnel seemed to feel a great deal of pressure to demonstrate recommended savings approaching 10 times the VE study fee in order to justify the VE program, even to the extent of presenting ideas outside the original constraints. This is an unhealthy situation in that it generates subsequent non-productive efforts on the part of the Designer, State, and EPA personnel to rebut ideas which cannot be implemented. It is recognized that VE of an excellent design will not show a 10:1 return and that lower savings in such a case will not adversely reflect on the VE program.

11. Most of the savings identified in the VE studies were related to initial costs. This may be partially accounted for by the fact that differences in O & M labor and maintenance materials for suggested changes are harder to quantify than changes in construction cost. Available data on O & M costs associated with various unit processes is now scattered among several publications or draft reports and it should be collected into a single published document supplemented by additonal studies, as needed, on individual pieces of equipment.

12. Because maintenance and operations costs are difficult to set over a long plant life, a sensitivity analysis performed on the life cycle costs may be beneficial. When LCC's for various alternates having different first costs are close, redetermining LCC's over a range of inflation rates may help to select the probable best alternate.

13. Resistance to implementation of VE ideas is unquestionably significant when design completion approached 70-80%. Increased construction management orientation of the VE teams at this point of the design is appropriate and can still produce significant savings.

14. Some of the VE reports reviewed in this effort were lacking in organization and clarity, making evaluation of even the basic consideration of which VE ideas were accepted and the associated savings very difficult. The proposal for the VE study should be required to contain the proposed format of the VE report.

15. Of those interviewed, a nearly universal dissatisfaction with available VE training workshops was expressed. The common theme of complaints was that too much time was spent on promotion of

the VE concept and too little time spent in hard discussions of the problem areas in applying VE techniques to wastewater projects.

16. Experience with VE appears to increase design personnel awareness of costs in the early stages of their next projcet.

17. VE team members must be isolated from their responsibilities on other projects during the VE workshop. Potential team members should be rejected if they have conflicting demands on their time or attention.

18. Care will be required on the part of EPA and all others involved to avoid use of the VE program to accomplish non-VE goals such as provision of detailed cost estimates of an existing design, a vehicle to achieve (or prevent) predetermined design changes desired by the State or Owner but resisted by the designer, or to needed outside design help which should be funded as part of the design fee.

19. Selection of an outside VE firm which is a competitor of the designer in the same geographic and technical area introduces a needless element of suspicion and distrust and should be avoided.

20. A team member from the Owners staff cannot be in the workshop merely to tell the teams what the Owner wants. Such a bias would reduce creativity.

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